PNE-900F (Rev.1)

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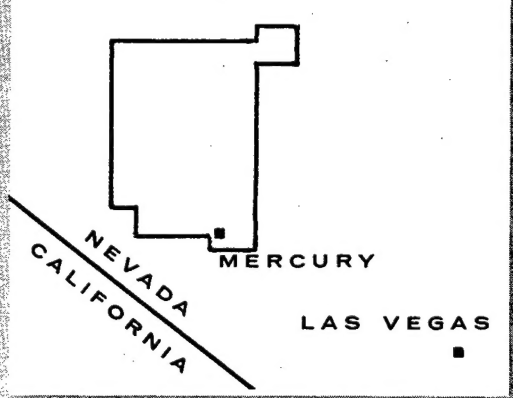
PNE-900F REV. I
FINAL REPORT

Dr. Richmond

Plowshare civil, industrial and scientific uses for nuclear explosives

UNITED STATES ATOMIC ENERGY COMMISSION / PLOWSHARE PROGRAM

NEVADA TEST SITE
April 14, 1965



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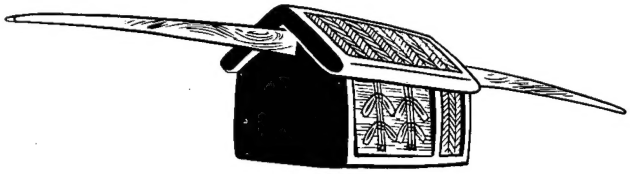

PROJECT
Palanquin

Ground Motion

R. ROHRER and R. W. TERHUNE
Lawrence Radiation Laboratory
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PROJECT PALANQUIN
GROUND MOTION

R. Rohrer
R. W. Terhune

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PROJECT PALANQUIN

GROUND MOTION

ABSTRACT

This report presents the data concerning the surface motion as a function of time for the Palanquin nuclear cratering event. A description of the experimentation and the general surface motion is given. The data for the surface motion time history are obtained from reading and analyzing, by means of digital computer, the film from high-speed photography of surface motion. Graphs of the vertical and horizontal displacement and vertical velocity of individual surface motion targets vs time are presented.

1. INTRODUCTION

Project Palanquin was a nuclear experiment in hard, dry rhyolite rock executed as part of the Plowshare program for development of nuclear excavation. Palanquin was fired on 14 April 1965 at approximately 0514.0105 (PST), 1214.0105 (GMT), in Area 20, Nevada Test Site. The resultant yield was 4.3 ± 0.4 kt.

Detailed study of the surface motion resulting from a nuclear cratering explosion is necessary in order to better understand cratering phenomena. Data desired include displacement and velocity of the surface motion as a function of time. These data will be used for analysis of the cratering physics and the relative importance of the contribution to cratering of spall and gas acceleration. Previous experience with nuclear cratering explosions in hard rock has been limited and the data obtained have been restricted by poor fiducial markers and loss of targets from the initial shock. Palanquin, therefore, presented an apportunity to obtain experimental data on surface motion from a large yield experiment in hard rock.

2. EXPERIMENTAL PROCEDURE

Three separate experiments were designed to obtain surface motion information on Palanquin. These were: (1) surface motion flares; (2) falling-mass experiment; (3) an accelerometer.

The surface motion flares had the function of determining the surface motion time history over the entire mound, up to the time of vent. The falling-mass experiment and the accelerometer had the function of determining the surface motion at times less than 100 milliseconds.

2.1 SURFACE MOTION PHOTOGRAPHY

The flare holder used for Palanquin is shown in Fig. 1. Magnesium flares of 750,000 candle power each were attached to the flare holders. The flare holders were 1.525 m (5 ft) high, weighed approximately 500 kg, and were anchored into the ground as shown in Fig. 2. This permits good coupling with the surface and simulates the actual surface motion.

The flare array was aligned in a general east-west direction as shown in Fig. 2. Photo station #1 was located 3.2 km south of this array, and on a line of sight perpendicular to the flare array. Fifteen hundred feet in front of the flare array in the direction of photo station #1, three fiducial flares of 750,000 candle power each were placed. These three flares served as a fiducial point for the flare array over ground zero. The purpose of the flares was to facilitate the reading and analysis of the film by a computer program (described elsewhere in this report) which gives the time history of the surface displacement.

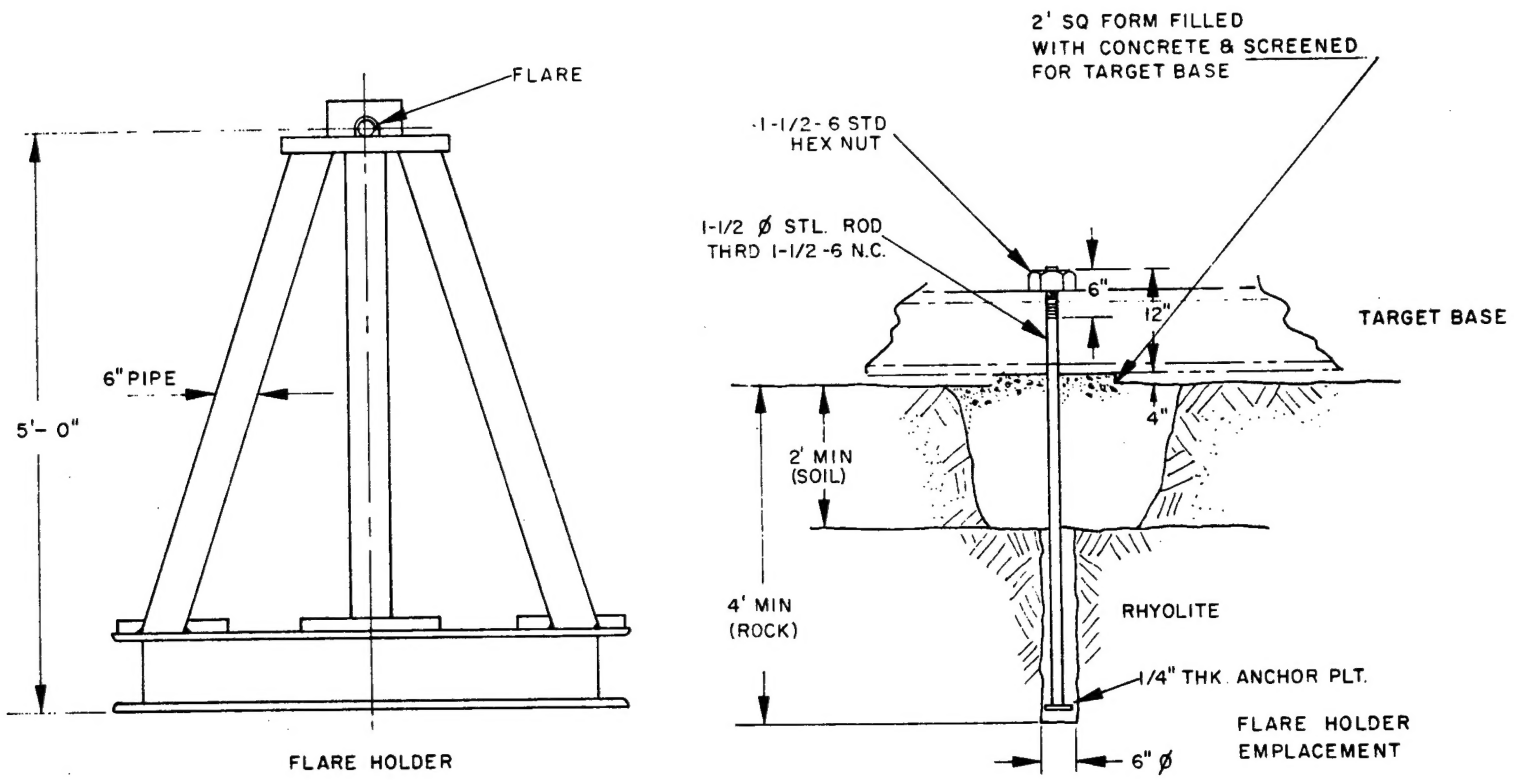


Fig. 1. Flare holder and emplacement.

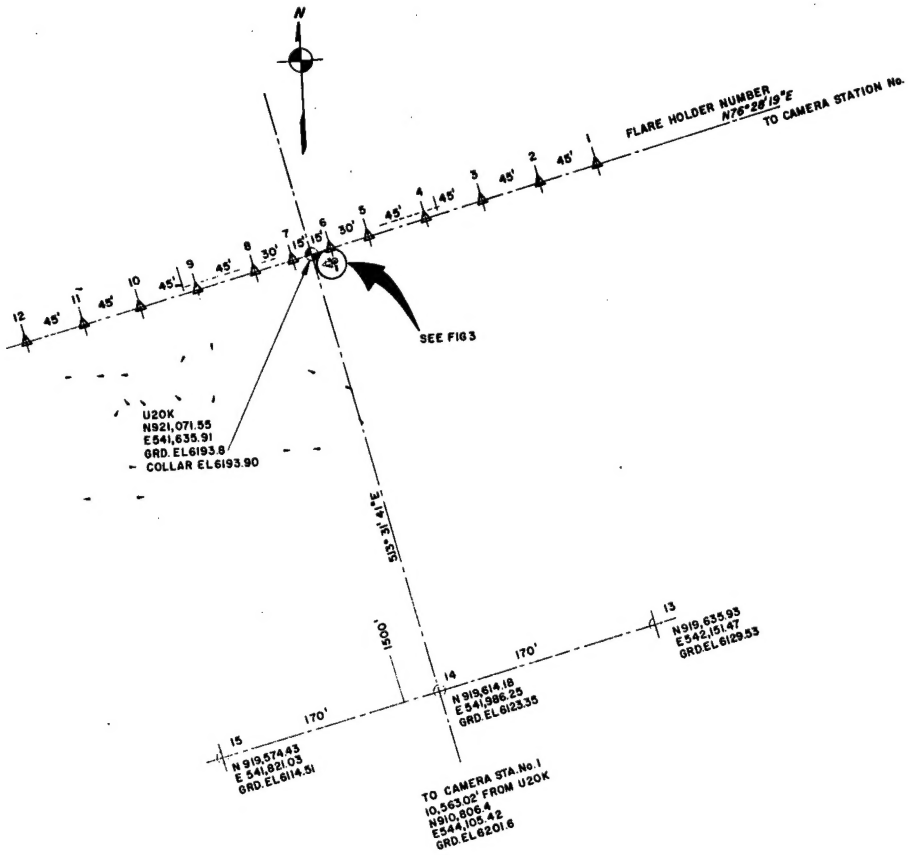


Fig. 2. Flare array.

This photography was accomplished by 4 cameras running at a framing rate of 1000 pps. By under-exposing and filtering the film, it was possible to increase the contrast between the flares and the background so that only the pin points of light from the flare appeared on the film.

2.2 FALLING-MASS EXPERIMENT

A 4 ft × 8 ft × 1-in. plywood target was mounted on a supporting frame similar to that used for the flares. Two white "Scotch Lite" strips 7.6 cm (3 in.) wide and 1.525 m (5 ft) apart were attached to the target. A standard 7.27-kg (16-lb) bowling ball was suspended in front of the target by means of a sash cord extended over a pulley which was supported by a gallows constructed from 7.6-cm (3-in.) pipe. The target had a weight of 1000 lb and was anchored into the ground 3 m ft from the emplacement hole as shown in Fig. 3. The ball was released at zero time by a detonator attached to the supporting sash cord. The relative displacement between the ball and target, which moves with the surface spall velocity is obtained from camera station #3. This camera station was located 1.74 km east of ground zero.

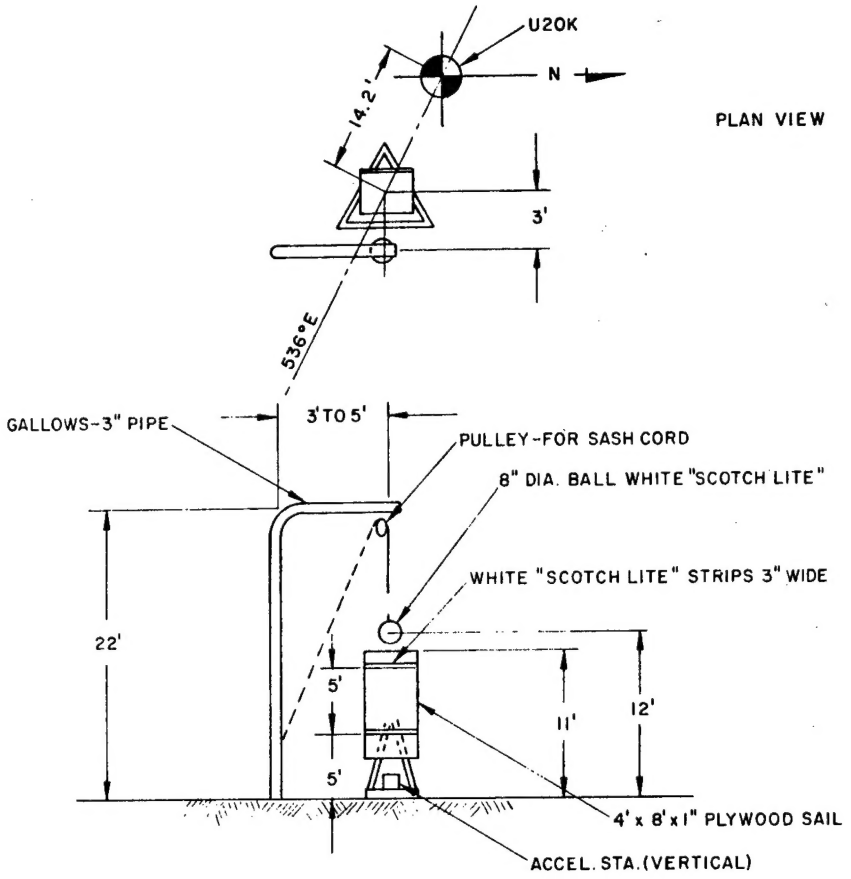


Fig. 3. Falling-mass experiment.

Two cameras at station #3 with a 1000-mm lens recorded the action of the bowling ball. Since this falling-mass experiment is of short duration, film with a running speed of 800 and 1000 frames per second was used.

2.3 ACCELEROMETER PROGRAM

One accelerometer to measure a vertical component of acceleration was bolted to the base of the background bowling ball target and covered with a steel shield. The accelerometer was an END #2261 type, which is a piezo-resistive bridge. The output was fed via cable to a bridge balance, dc amplifier, and into a tape recorder at the trailer park 1.8 km from ground zero.

3. RESULTS

3.1 GENERAL MOUND RISE HISTORY

The quantatative history of the mound rise for Palanquin was determined from the flare photography obtained at camera station #1, two miles to the south of ground zero. A luminous jet of gas assumed to consist of iron vapor and air erupted from a diagnostic line of sight pipe which was approximately 6 in. in diameter and extended from the device to the surface at 0 + 35 msec obscuring the two close in flares 4,575 m on either side of ground zero; this luminosity continued until 90 ± 5 msec, by which time this initial jet had subsided and it was possible to again locate the two close-in flares. Within the resolution of the viewing system, no apparent surface motion had occurred. At 600 ± 25 msec, a second vent occurred. This second vent consisted of a plug of material about 9 m in diameter which appeared to be ejected from the emplacement hole in one violent motion. The plug included rock, the emplacement casing, and the line-of-sight pipe. The size of the vent continued to increase and had attained a diameter of 64 m by 1.5 sec. At the beginning of the second vent, the surface of the ground had risen about 9 m.

3.2 ACCELEROMETER AND FALLING-MASS EXPERIMENT

No meaningful data was recorded in the accelerometer program. Apparently the early vent at 35 msec destroyed the cable.

The falling-mass experiment was also unsuccessful since the early vent obscured the bowling ball and the target during the anticipated first motion.

3.3 EYEBALL FILM ANALYSIS

The film, from the photography of the flares, was read by the "Eyeball" program on the PDPI digital computer. Using the initial latitude, longitude, and elevation coordinates surveyed for each target and fiducial, the PDPI digitized coordinate information was scaled, transformed to a common reference system, and then plotted by the IBM 7094 computer.[1]

The timing marks on the film were missing for the first 150 msec after zero time. Figure 4 shows a plot of the framing rate of the camera vs time as determined from the existing timing marks. An average timing rate of 970 frames/sec was chosen, resulting in an error of +5% in velocity measurements during the early part of the record, and -1.5% at late times.

[1] R. W. Terhune, R. L. Fulton, and J. B. Knox, "Reduction of Photographic Surface Motion Data by Digital Computer," University of California, Lawrence Radiation Laboratory, Livermore, California, UCRL-14155, May 1965.

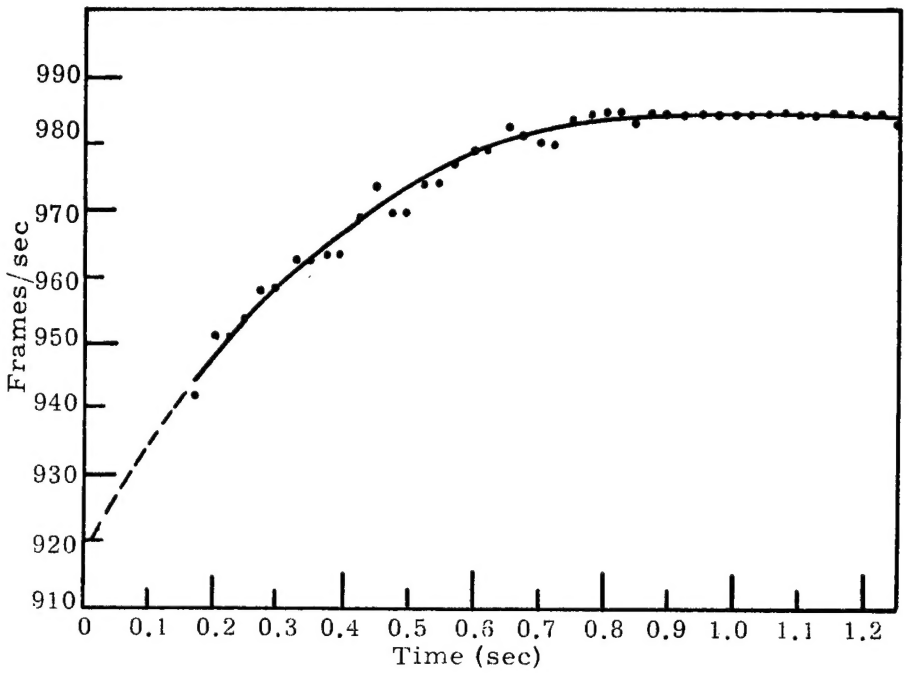


Fig. 4. Camera framing as a function of time.

Figures 5 through 16 show the vertical displacement data for targets 1-12, respectivley. Similarly, as obtained from the "Eyeball" program, Figs. 17 through 28 show the horizontal displacement data. Each dot represents a data point. The region of missing data is due to the effect of the early vent on the PDPI reading system.

Figure 30 is a hodograph of the mound displacement constructed from the data shown in Figs. 5 through 28. Note that the scale is distorted by a factor of 10 between the horizontal and vertical.

Figure 29 is a plot of the velocities smoothed with a smoothing parameter of P = 80 for each target. P is the ratio of the number of observations to the minimum number of observations required in the absence of noise. In this context P times the total time period of observations is the effective data interval.[1]

Some of the possible sources of errors contained in the data, excluding the timing, are as follows:

(a) Errors in determining the correct position of the center of the flare. This may be the result of the smoke partially obscuring the flare or from reflections off the smoke being interpreted as part of the flare image.

(b) Errors in scaling or in transposing coordinates. This can result from the smoke causing the same errors in the fiducials.

(c) Flare image is on the other of 2 to 3 film grain sizes. Consequently, neighboring grains were exposed resulting in a distorted and larger flare image on the film.

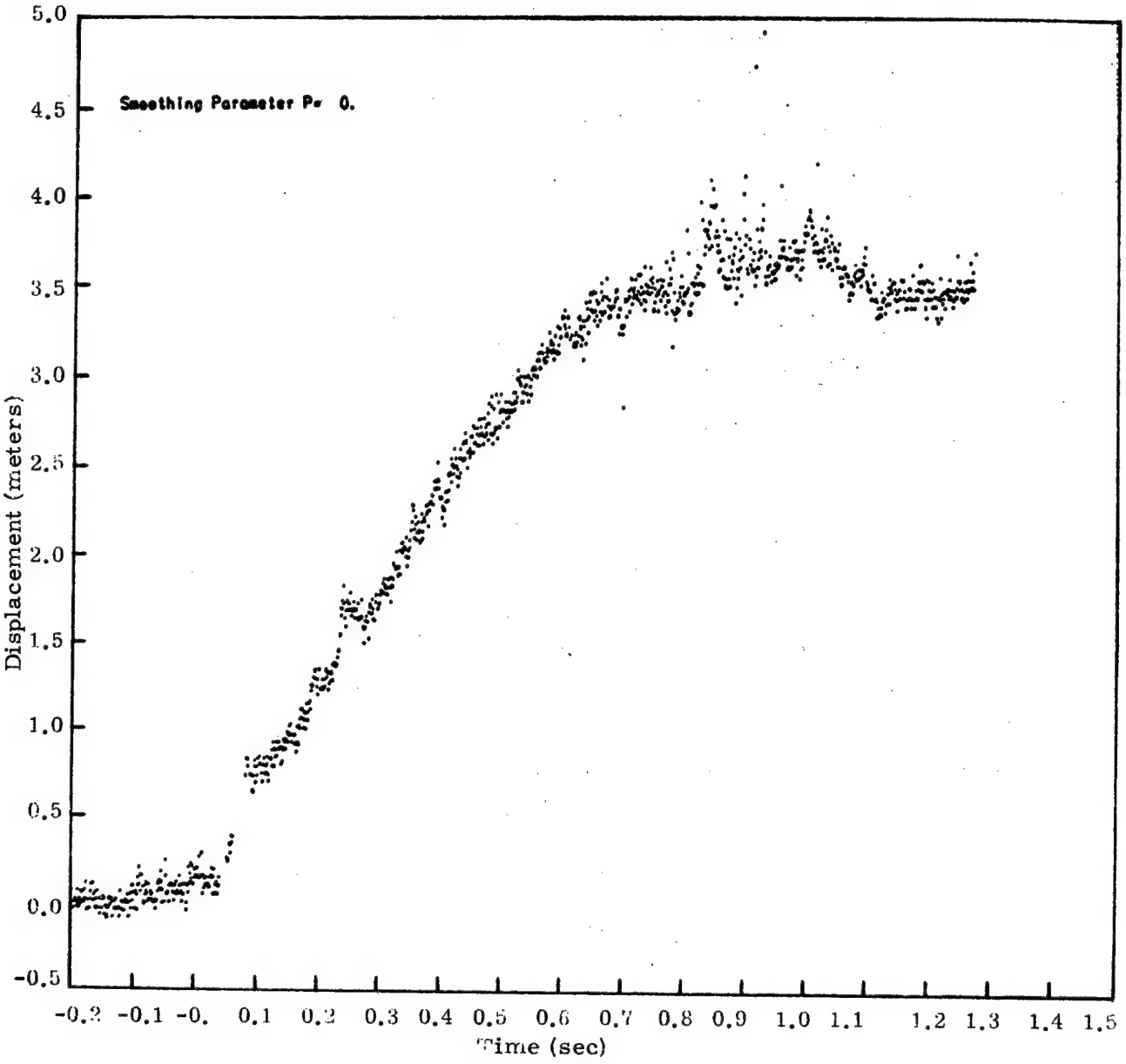


Fig. 5. Vertical displacement, Target 1.

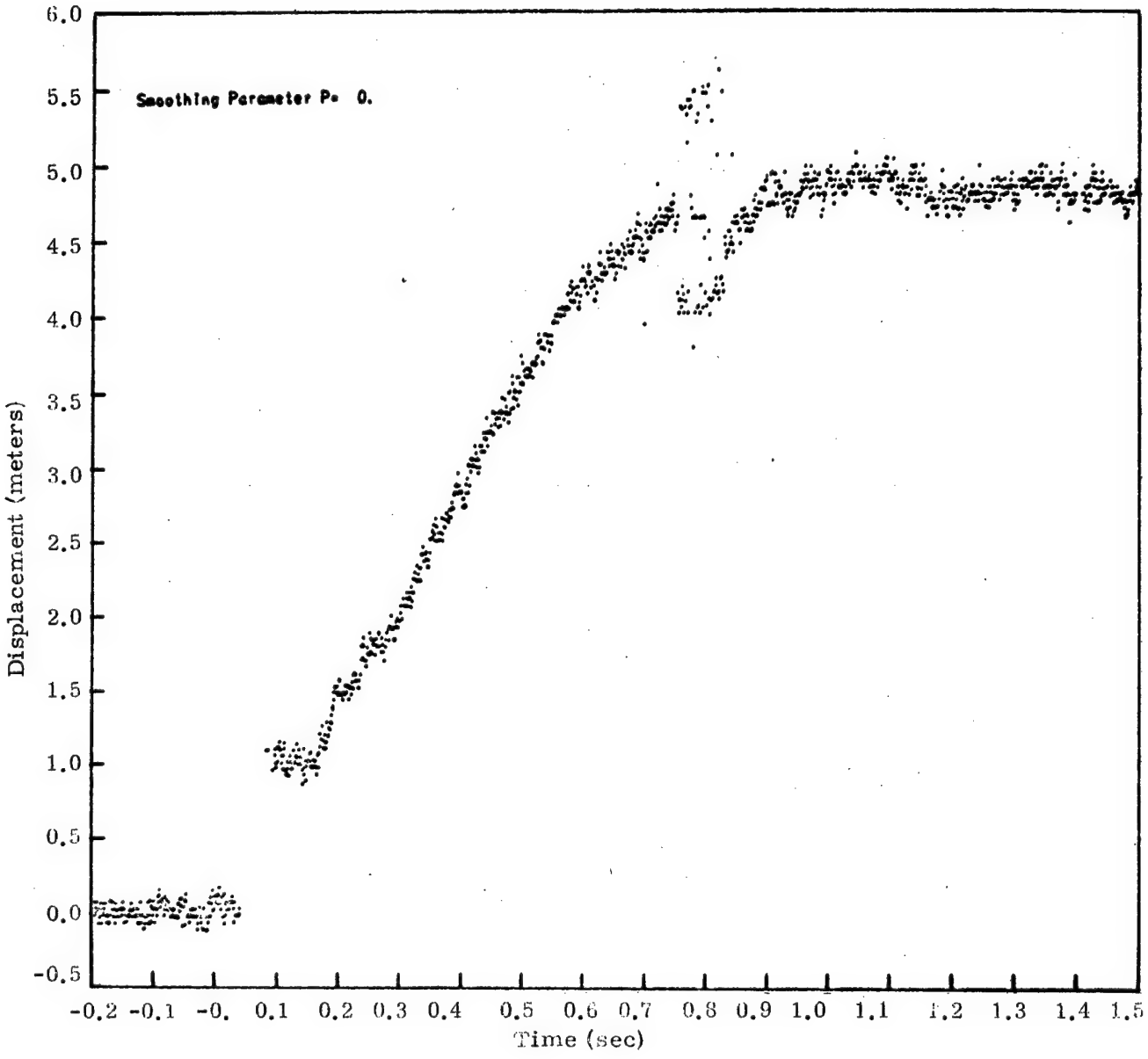


Fig. 6. Vertical displacement, Target 2.

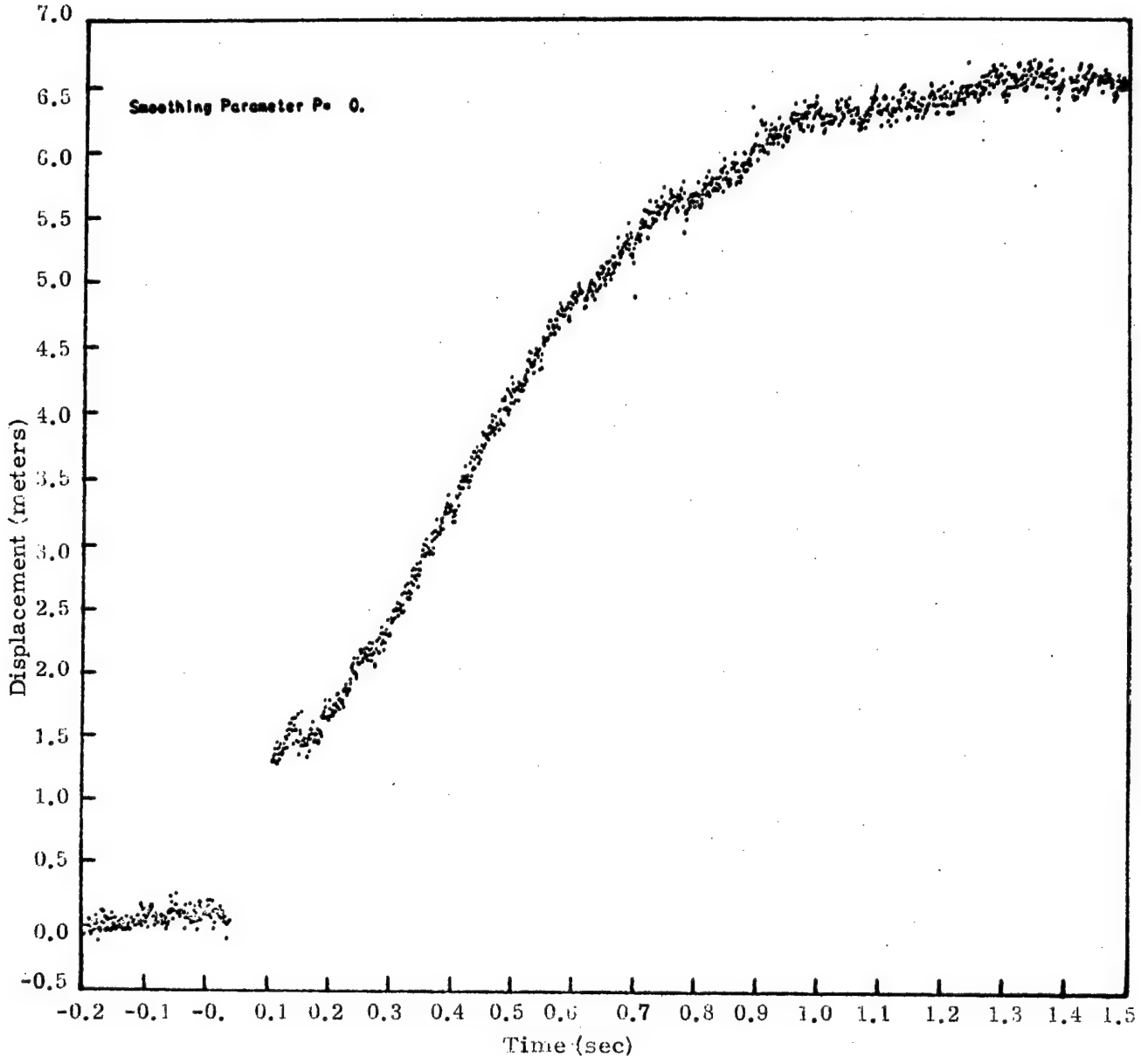


Fig. 7. Vertical displacement, Target 3.

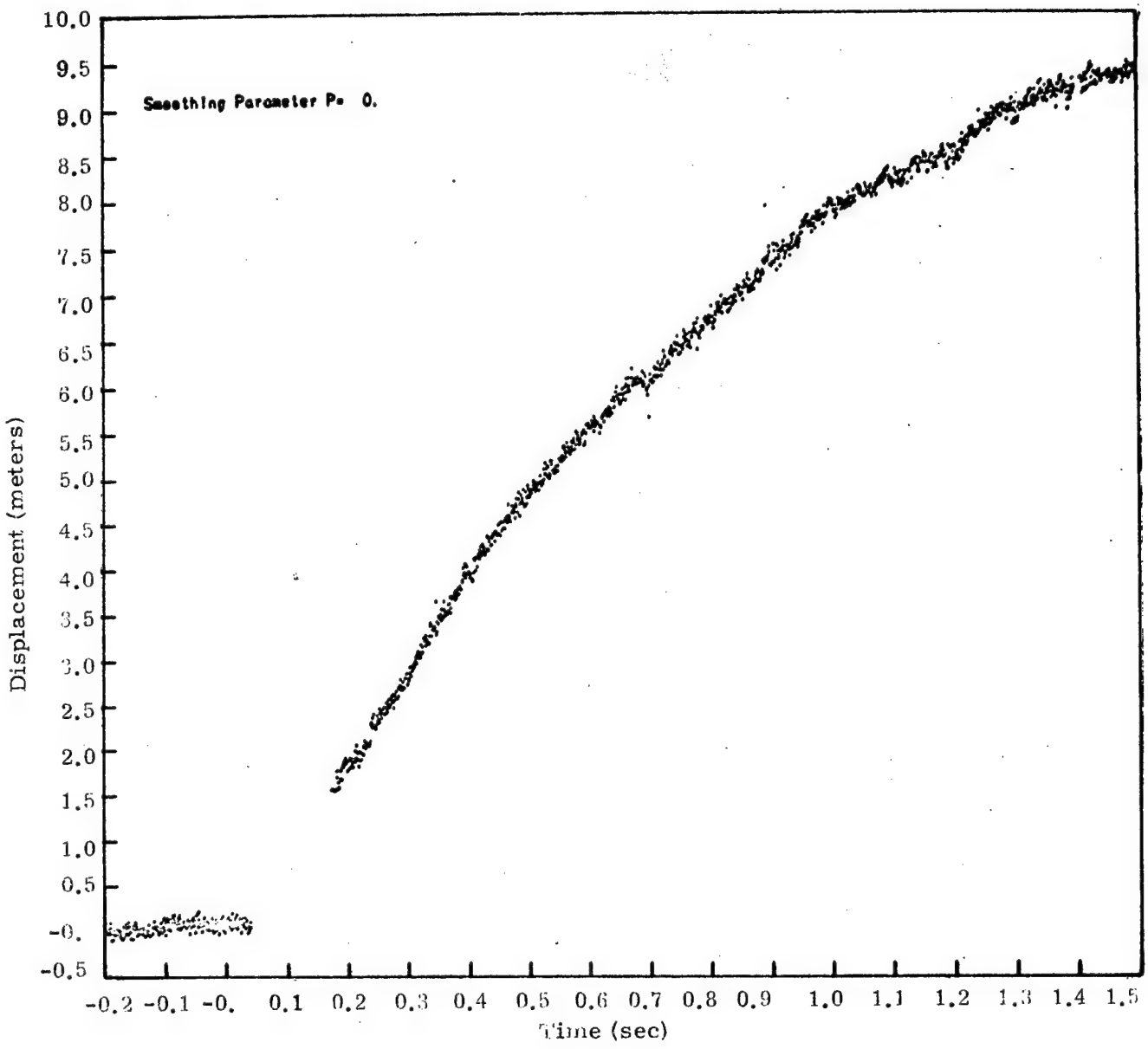


Fig. 8. Vertical displacement, Target 4.

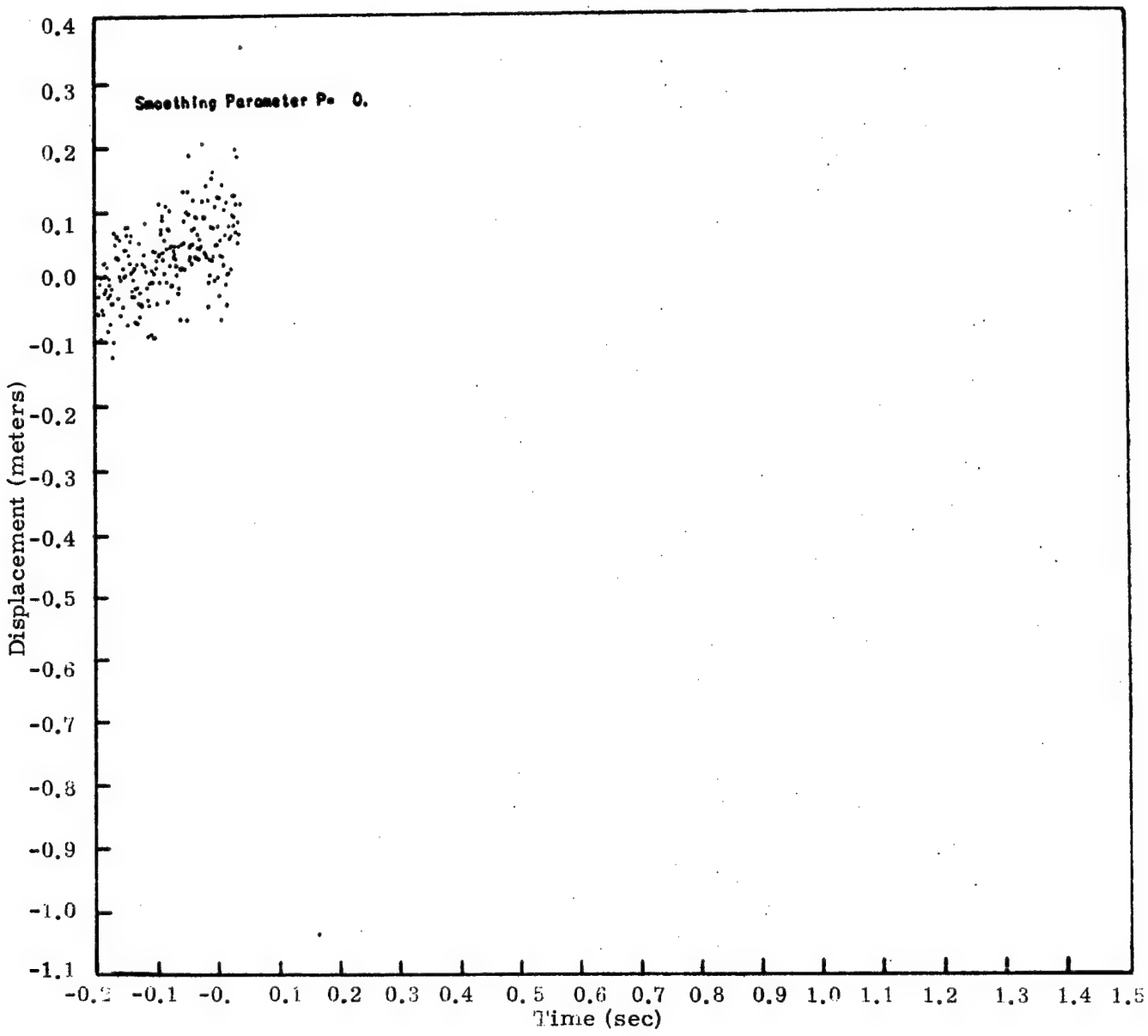


Fig. 9. Vertical displacement, Target 5.

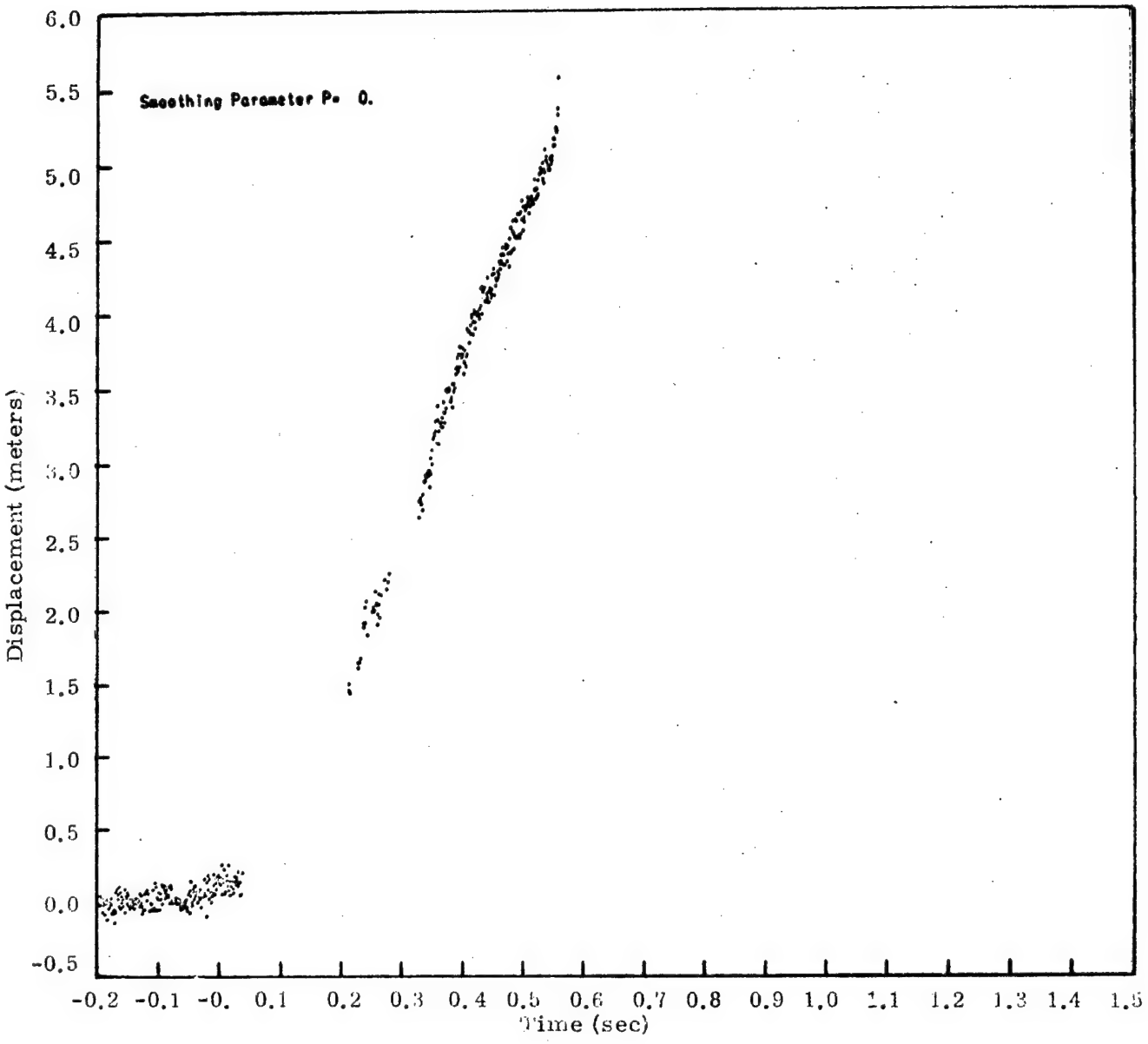


Fig. 10. Vertical displacement, Target 6.

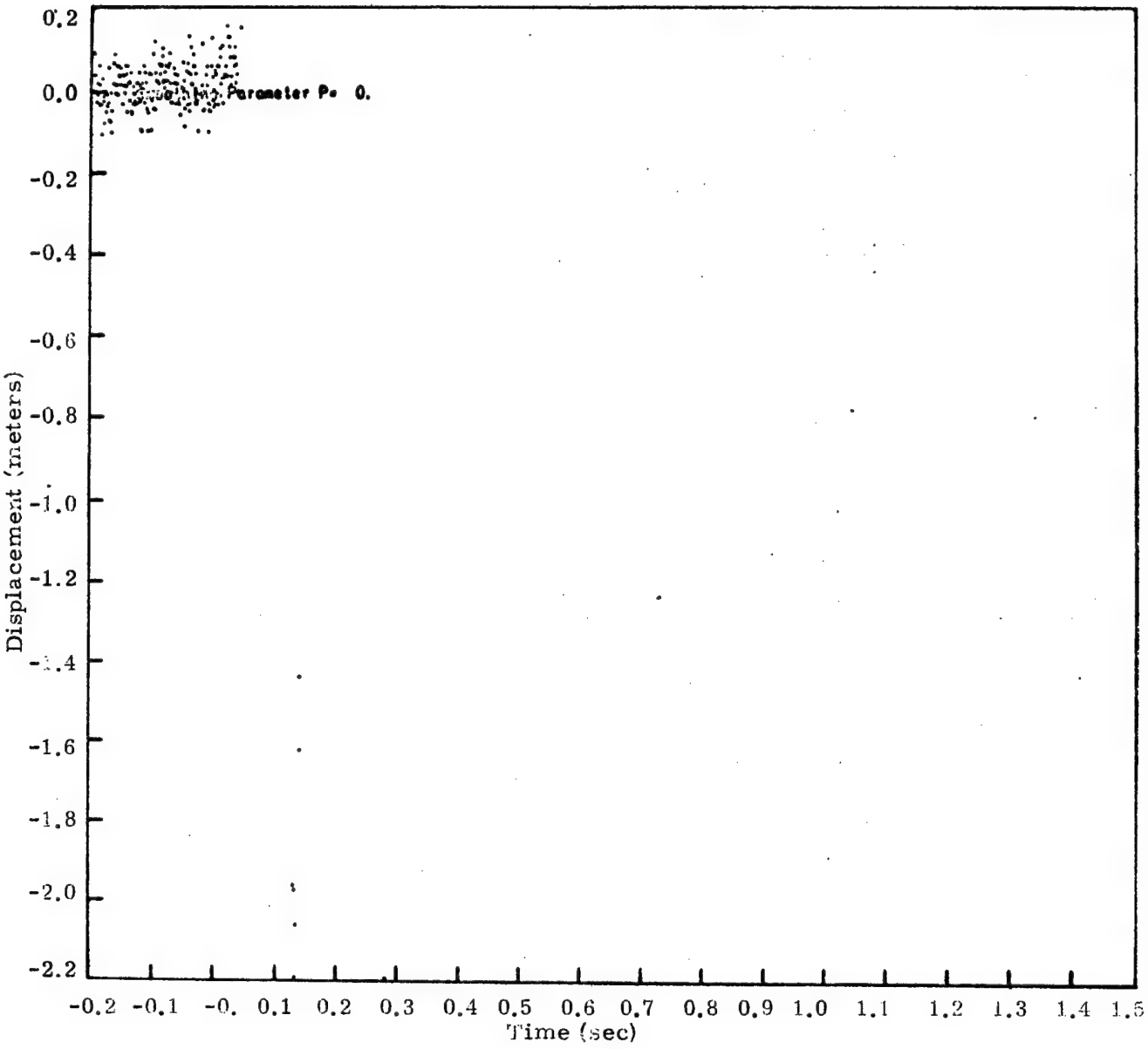


Fig. 11. Vertical displacement, Target 7.

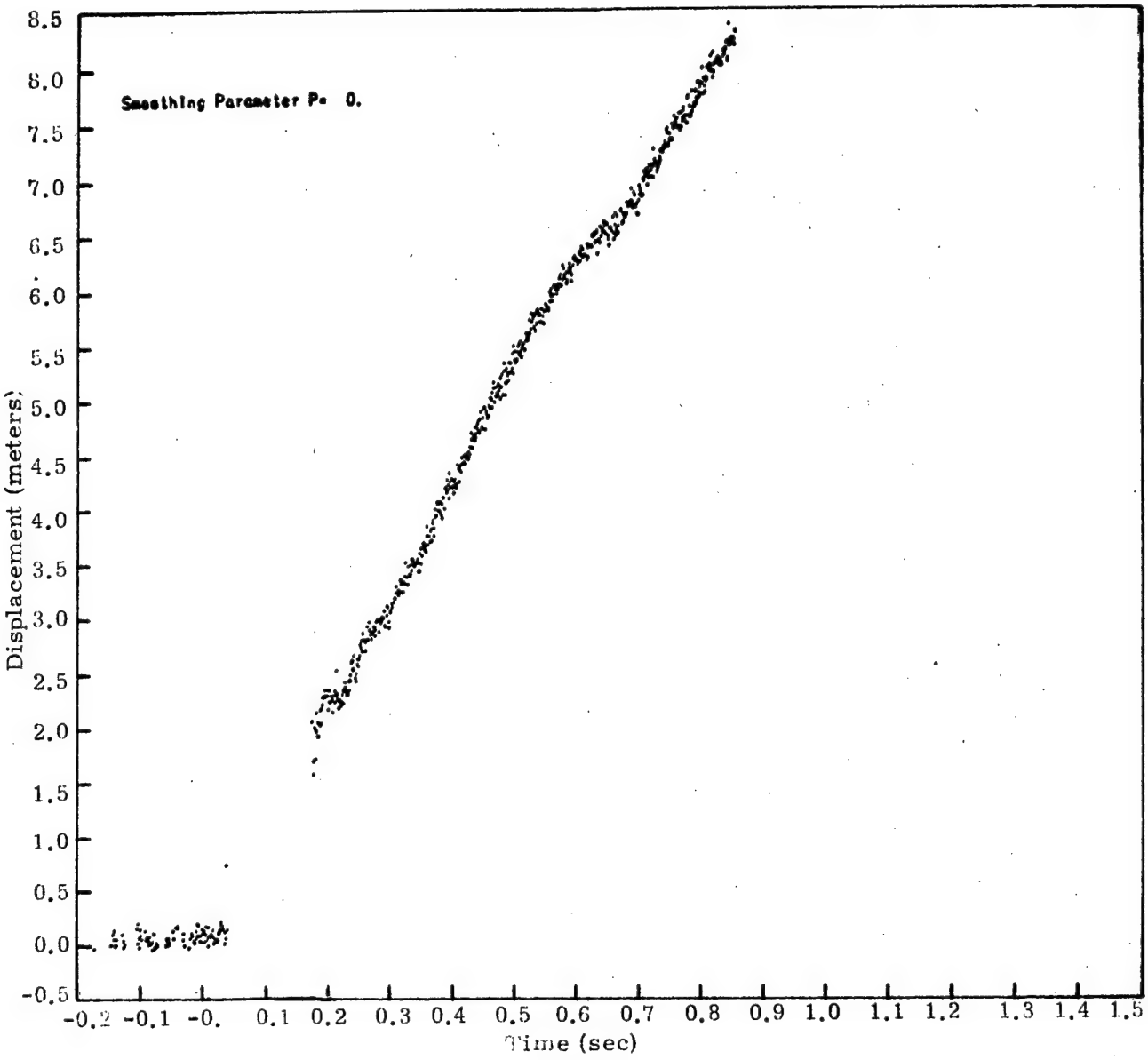


Fig. 12. Vertical displacement, Target 8.

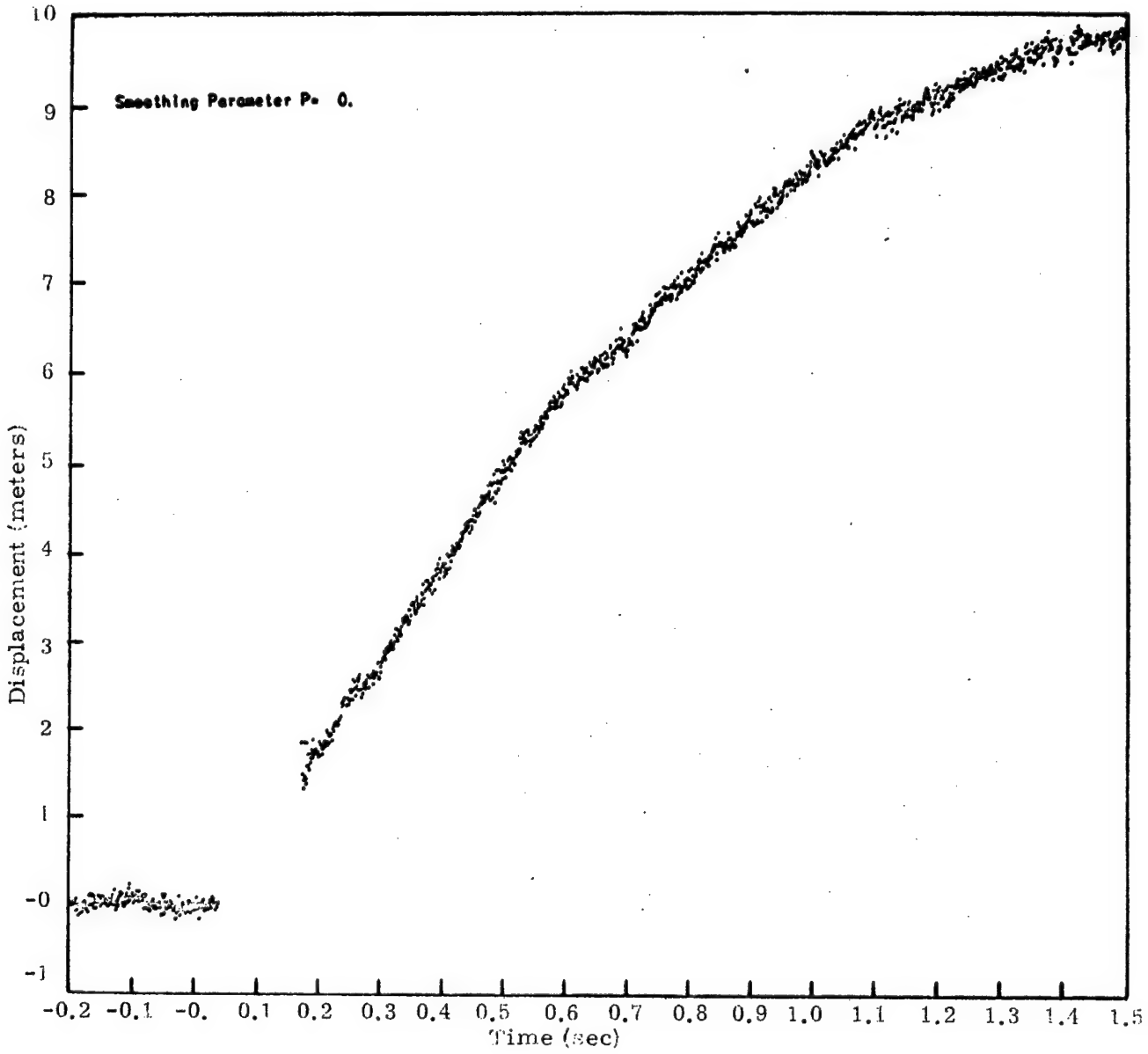


Fig. 13. Vertical displacement, Target 9.

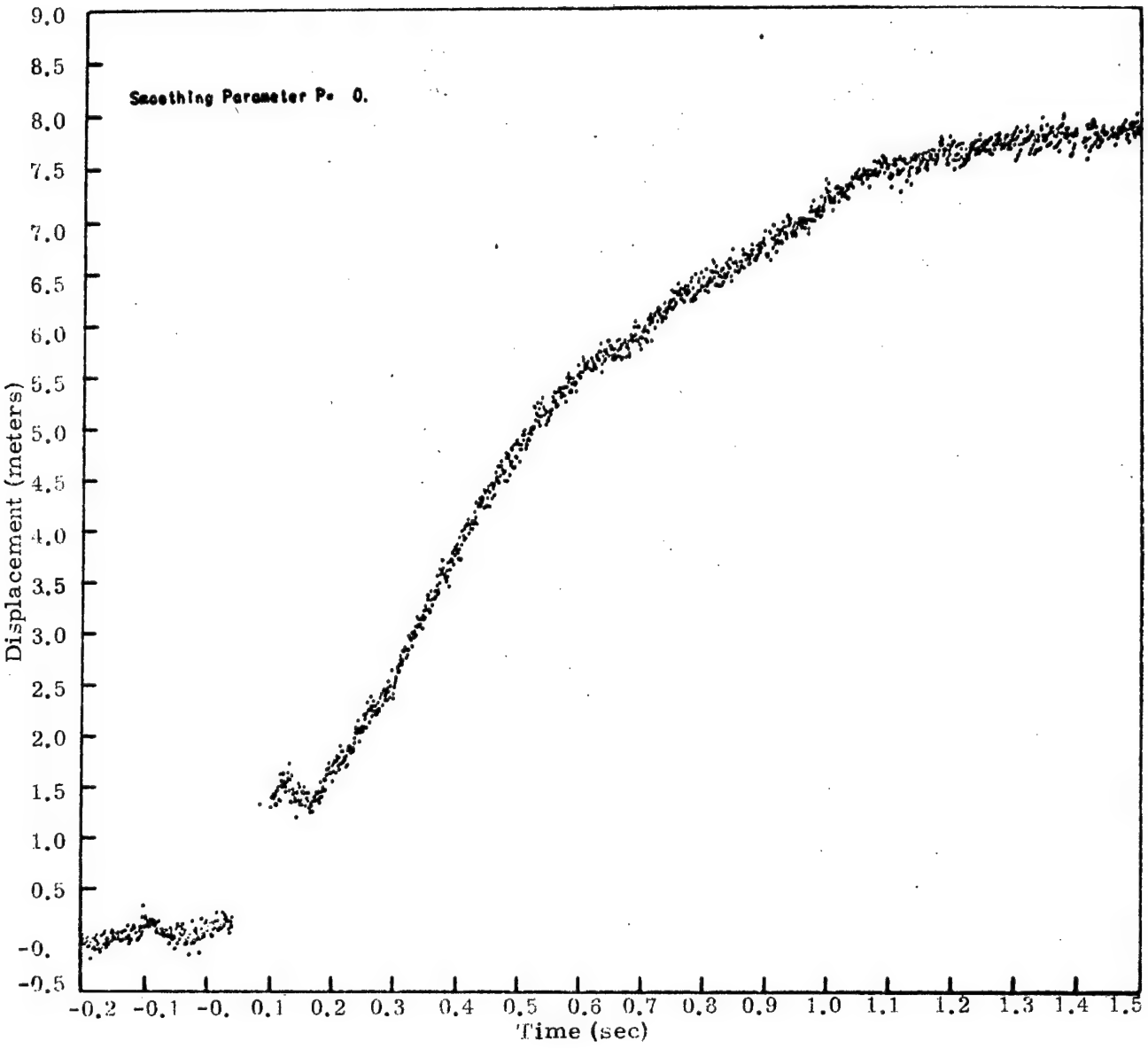


Fig. 14. Vertical displacement, Target 10.

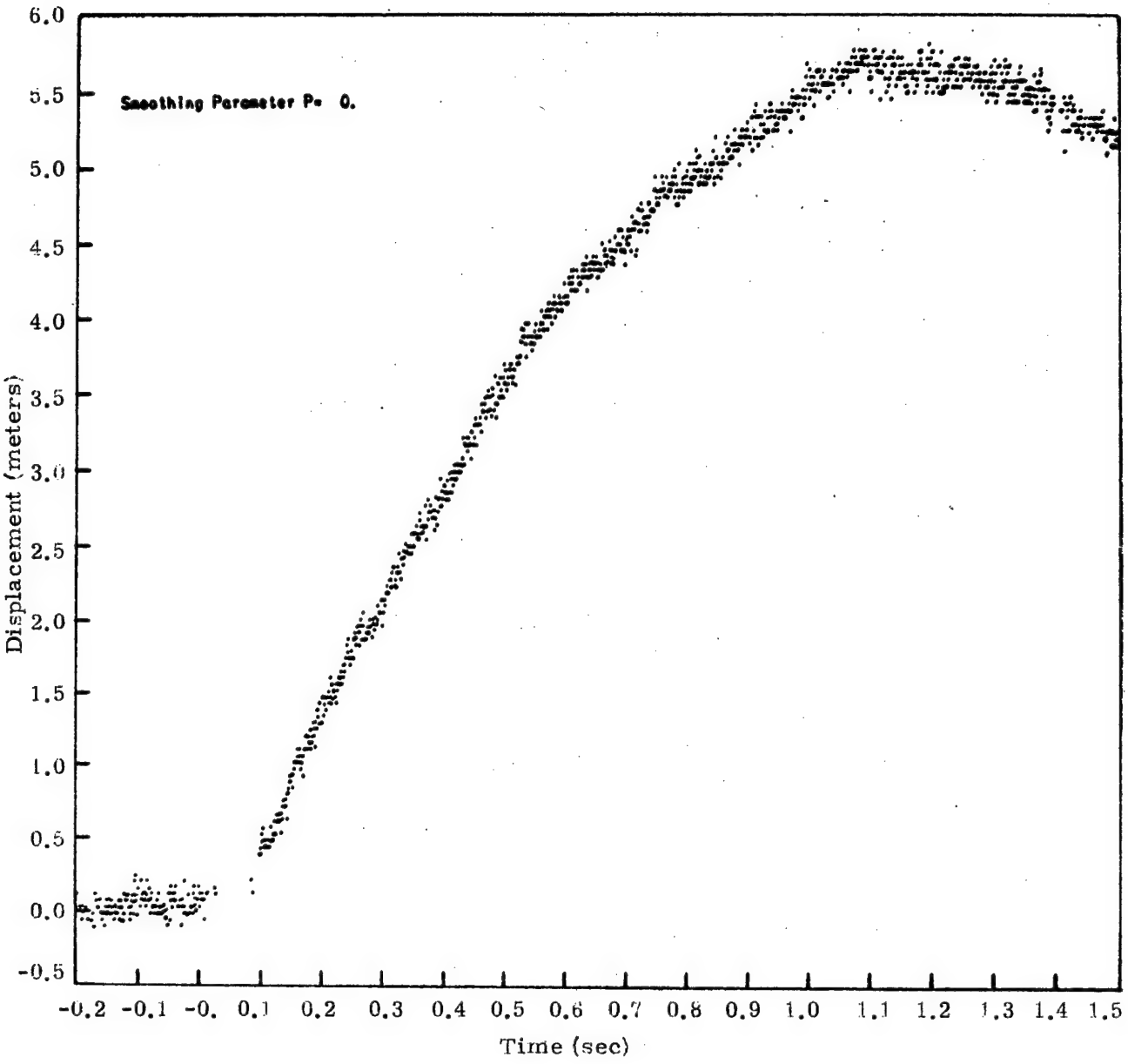


Fig. 15. Vertical displacement, Target 11.

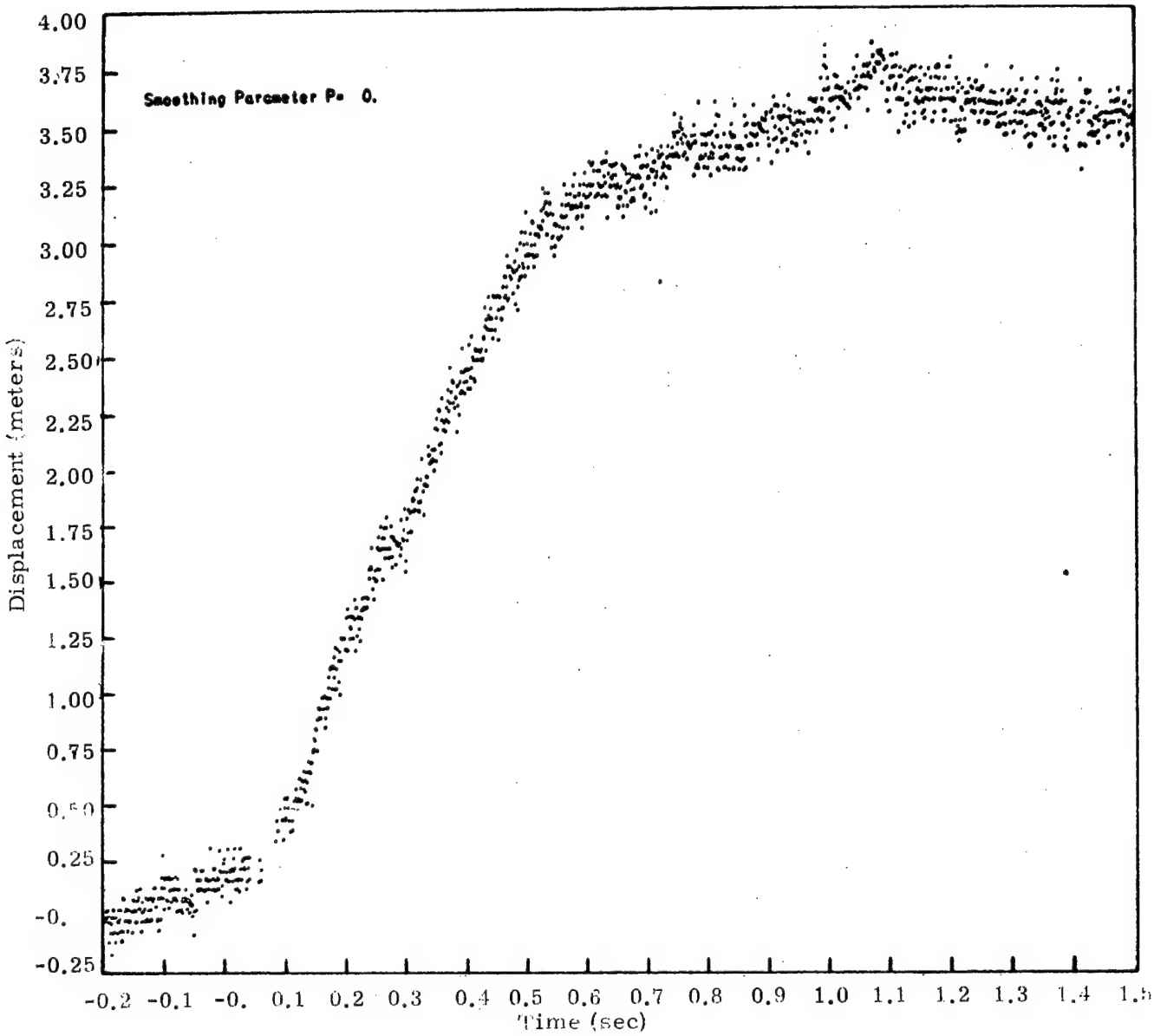


Fig. 16. Vertical displacement, Target 12.

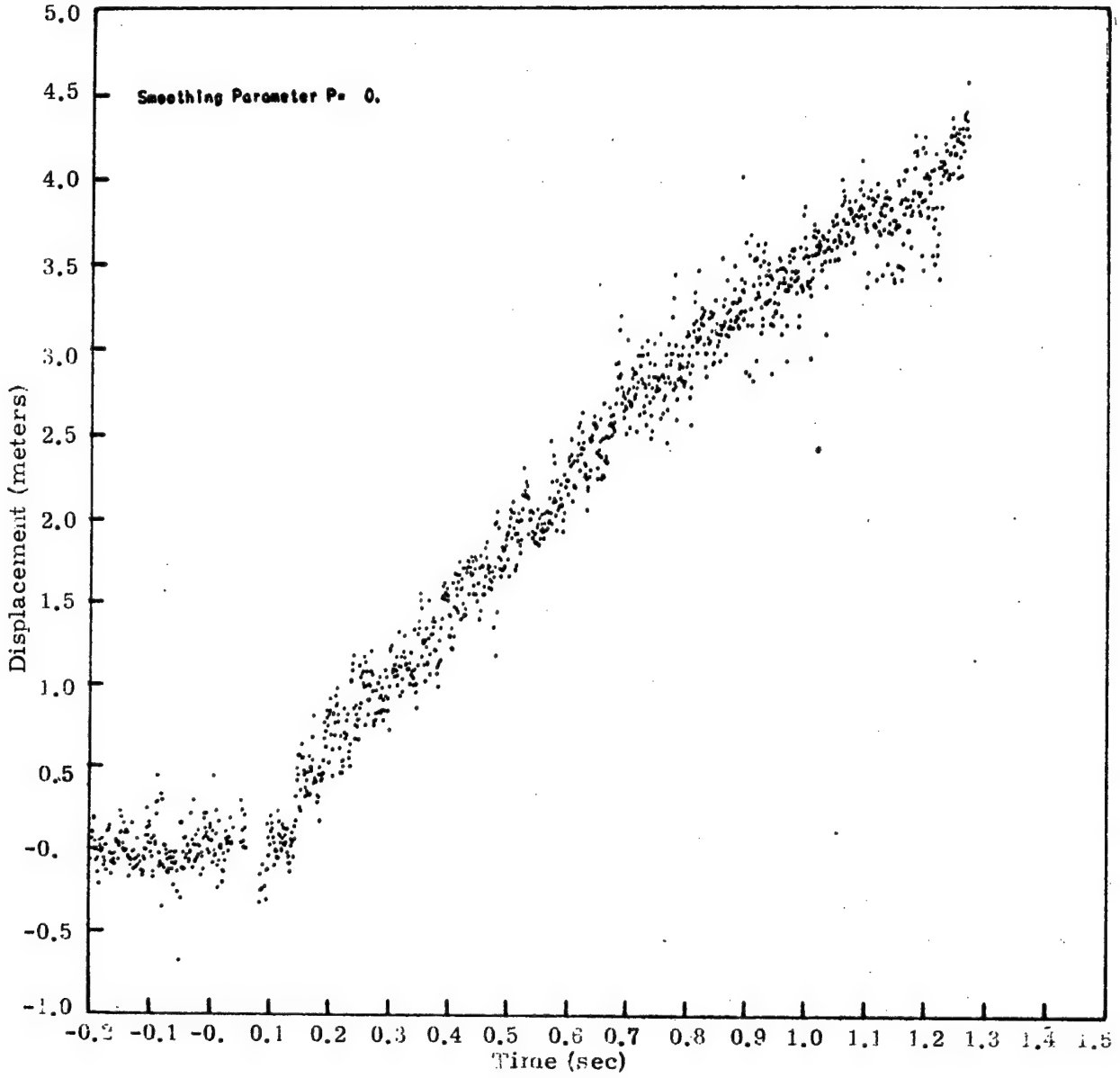


Fig. 17. Horizontal displacement, Target 1.

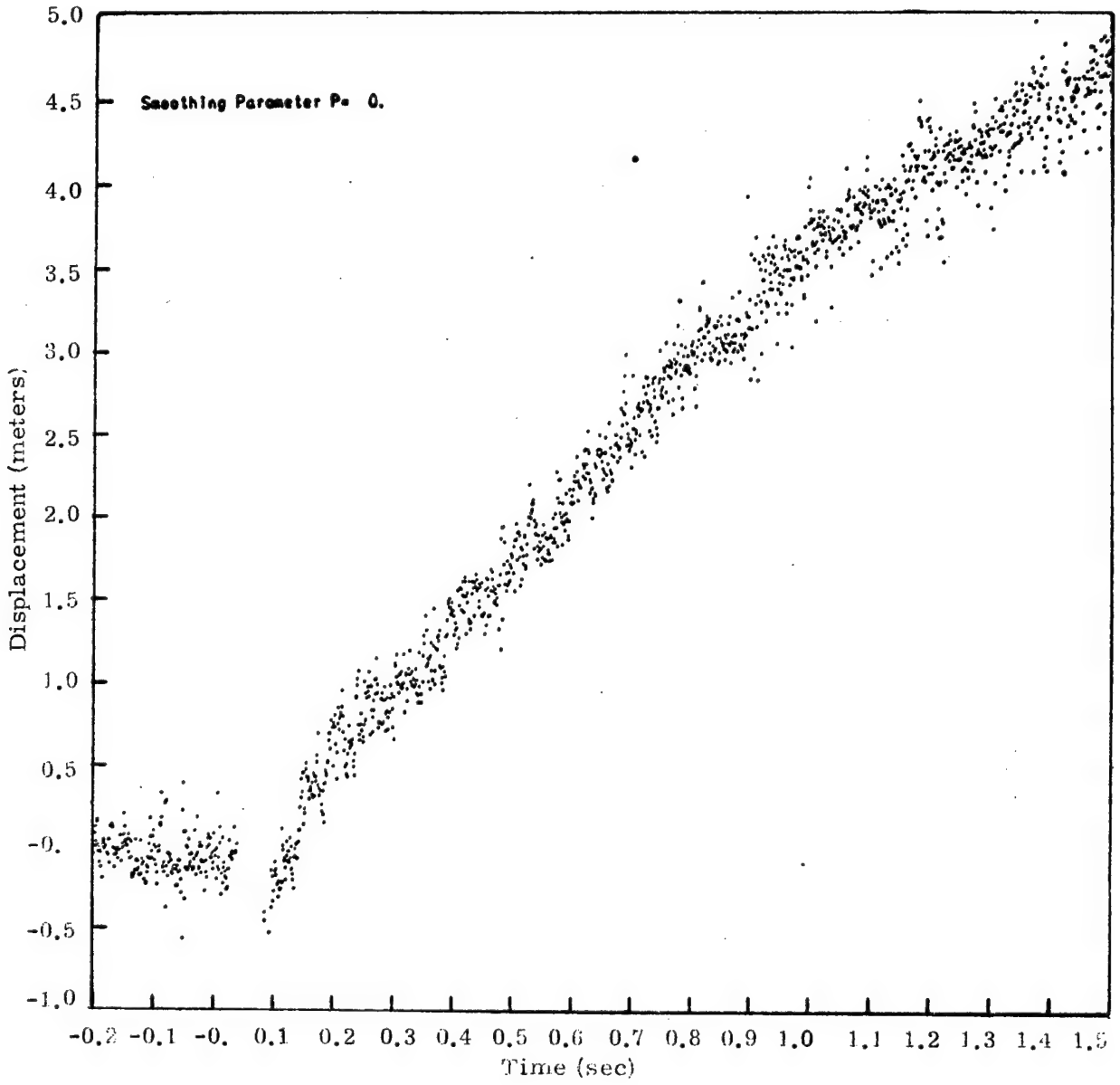


Fig. 18. Horizontal displacement, Target 2.

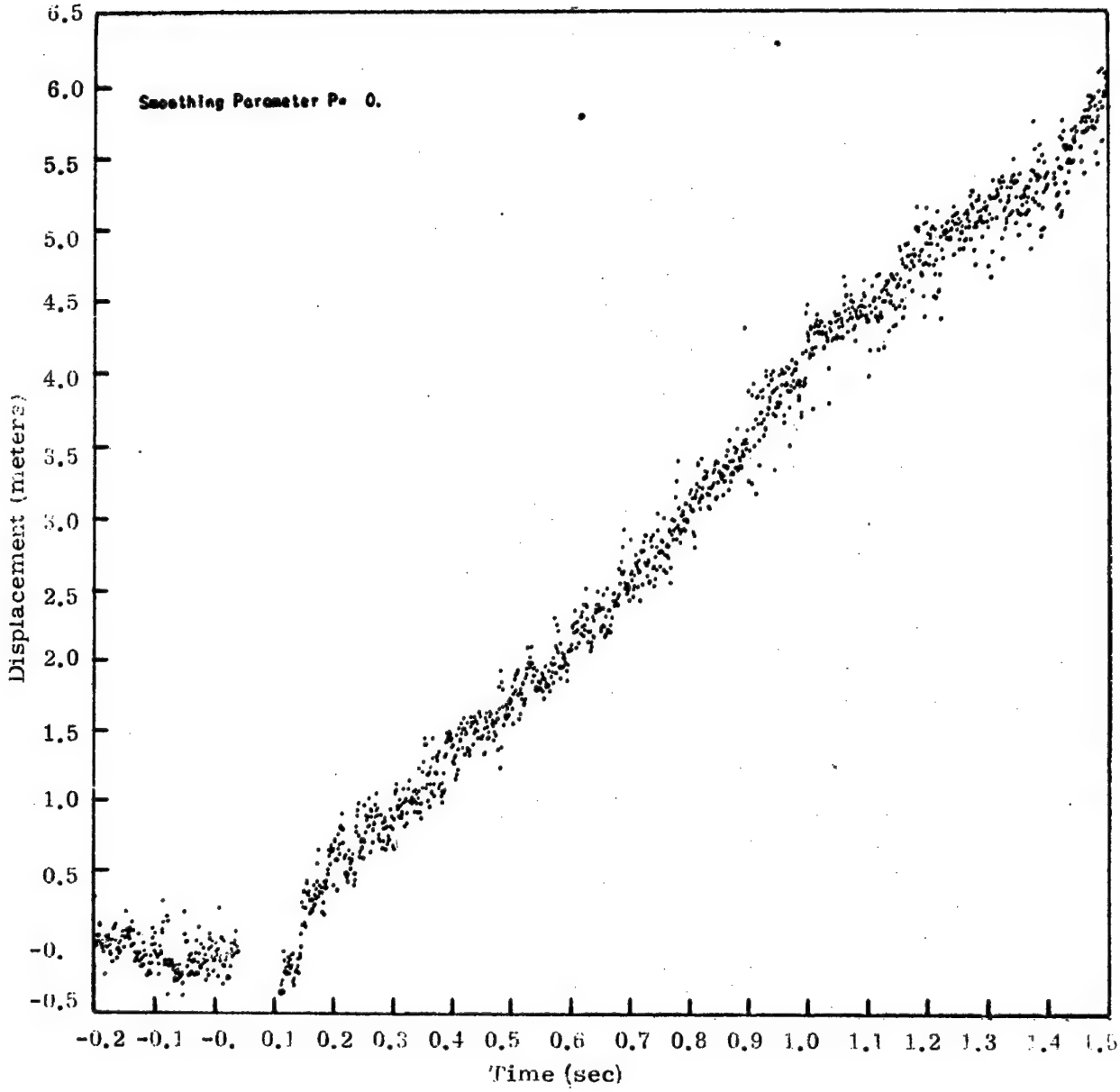


Fig. 19. Horizontal displacement, Target 3.

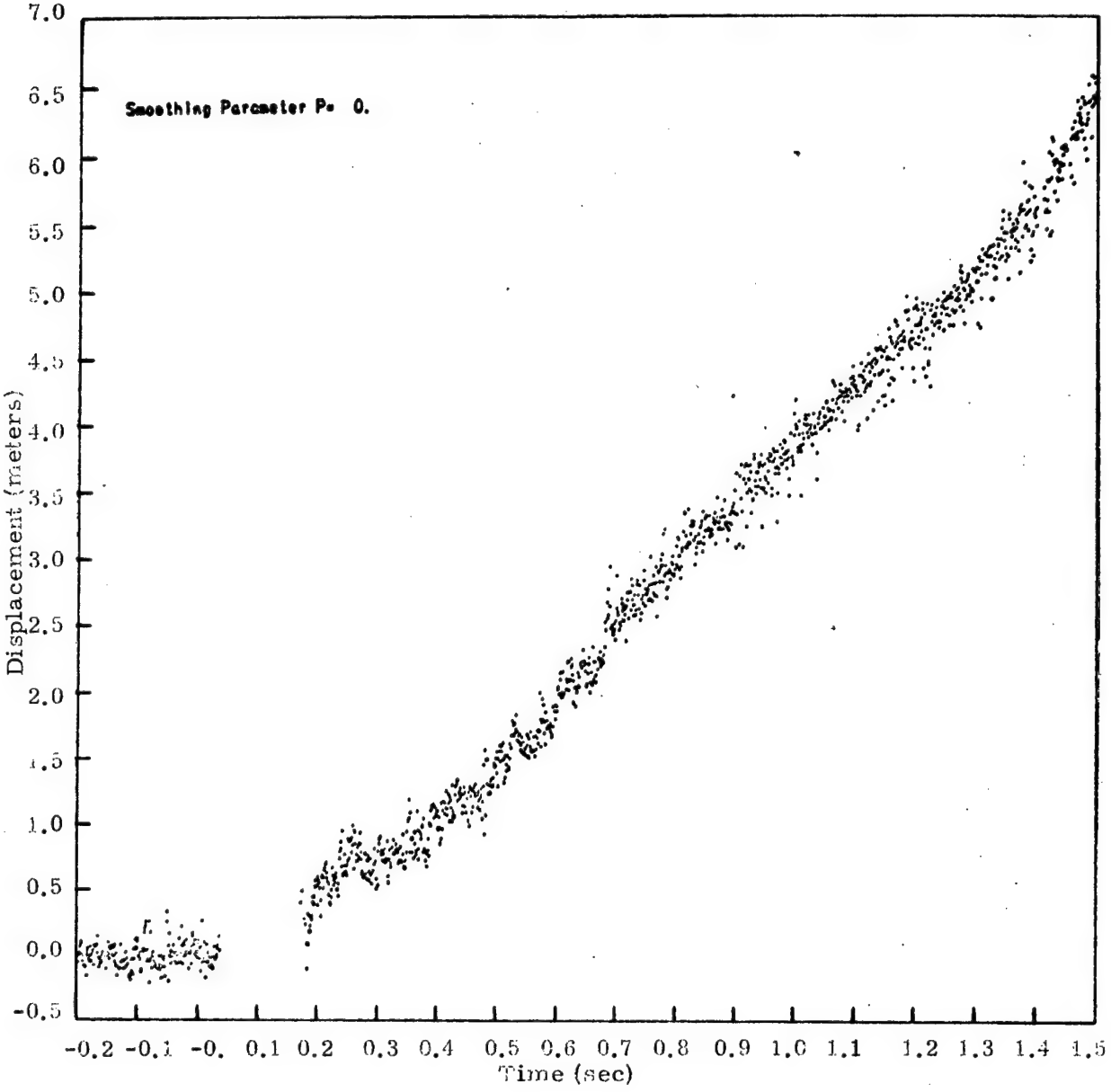
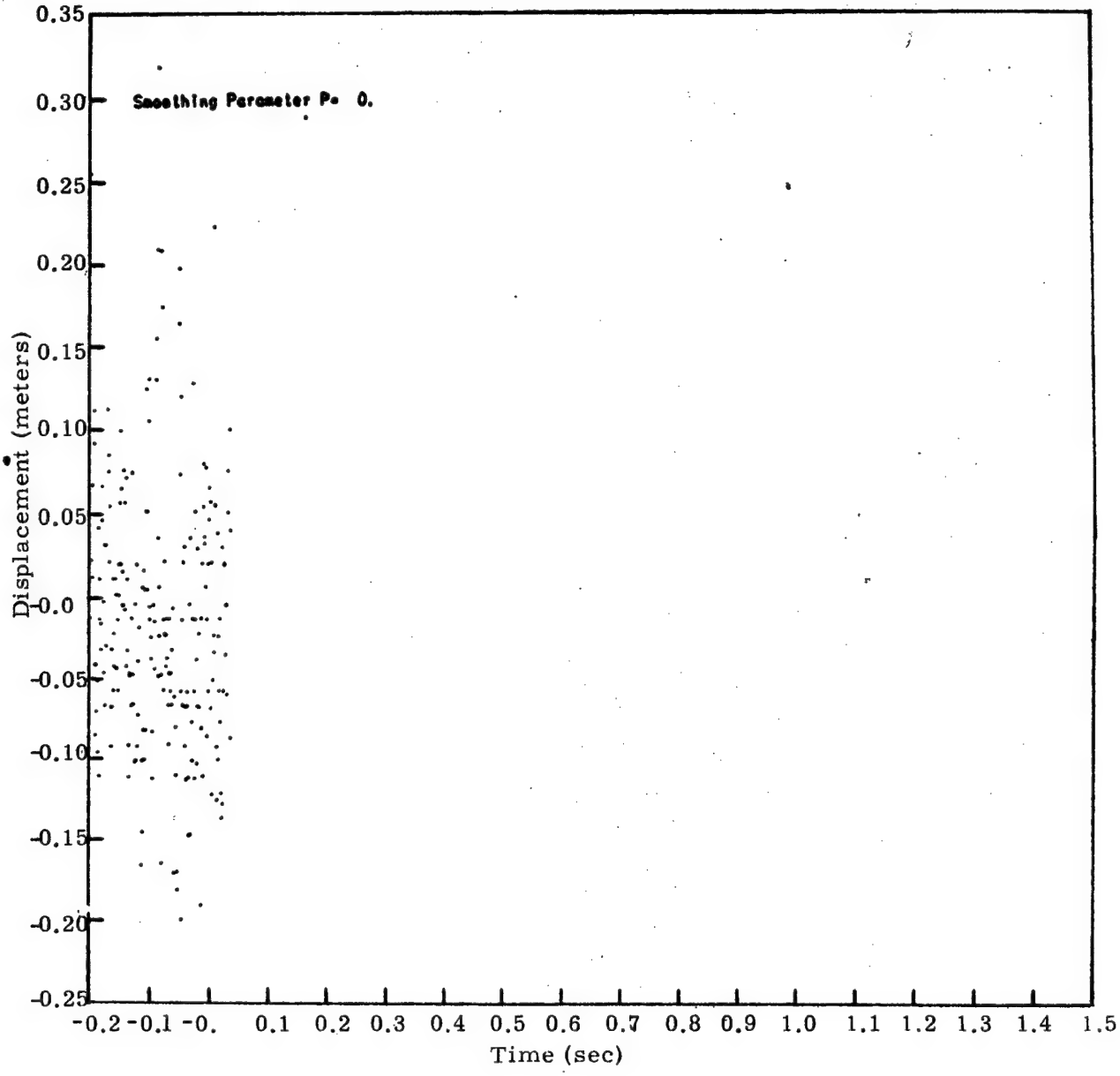


Fig. 20. Horizontal displacement, Target 4.



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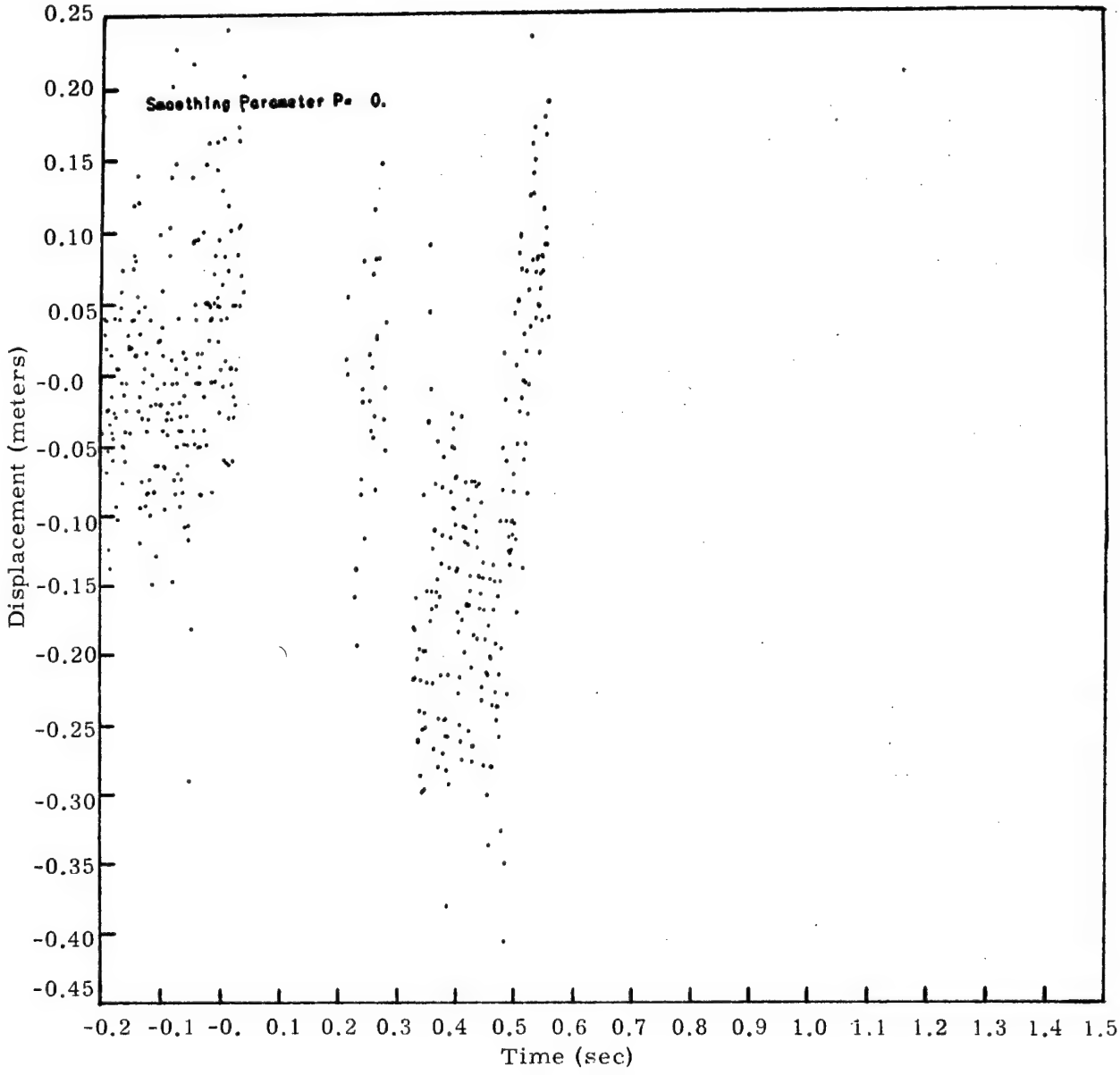

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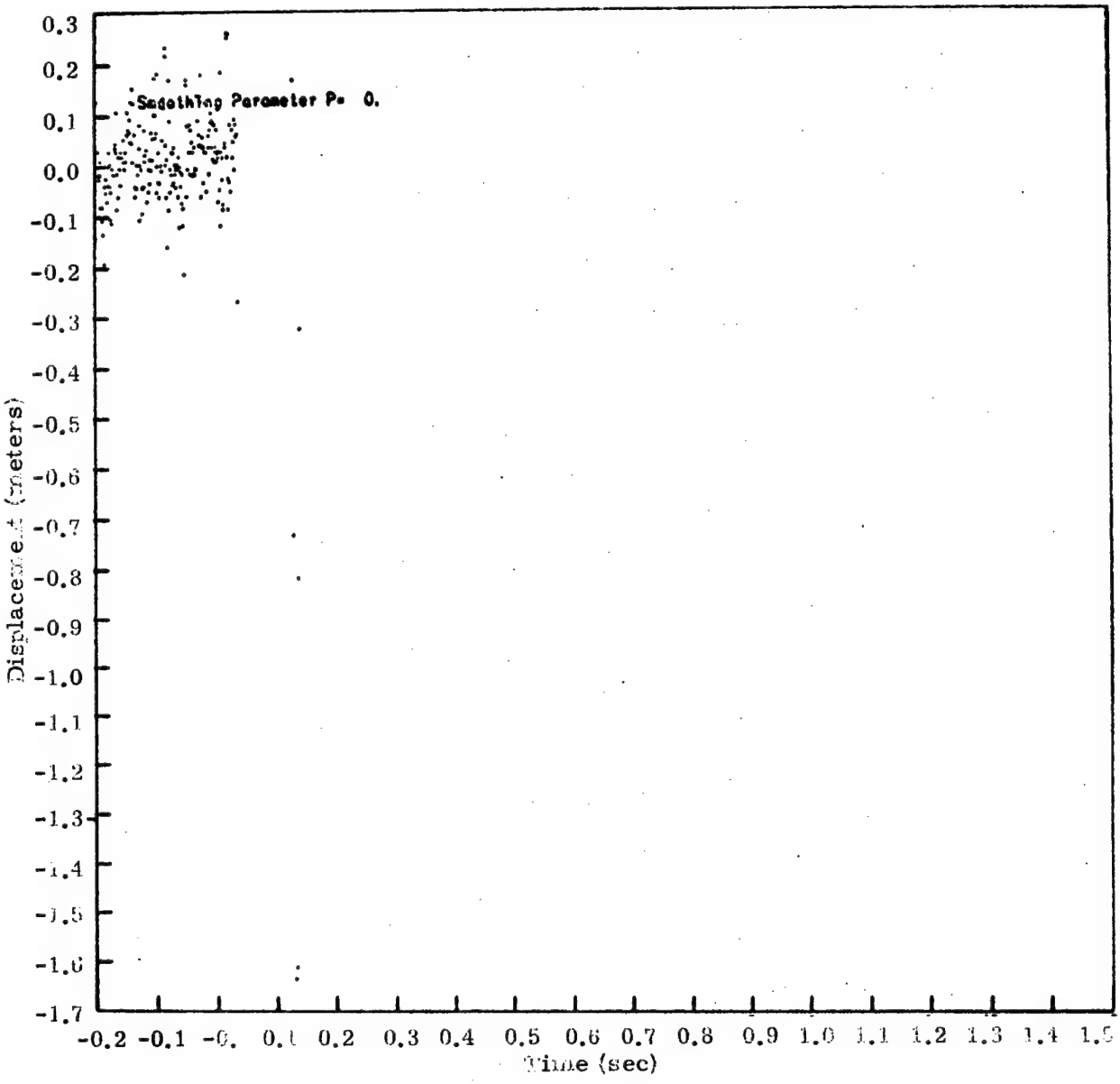

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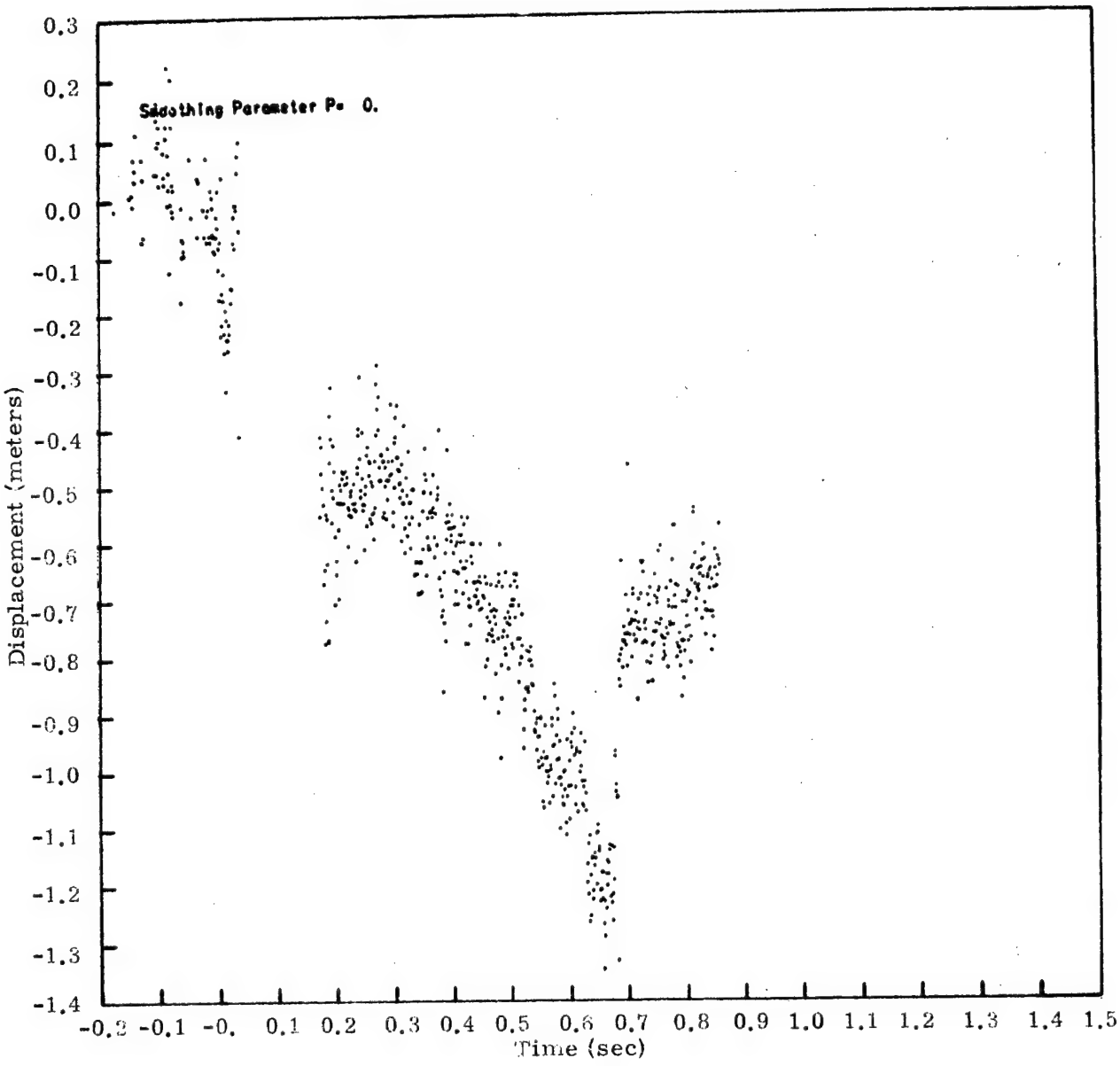

Fig. 24. Horizontal displacement, Target 8.

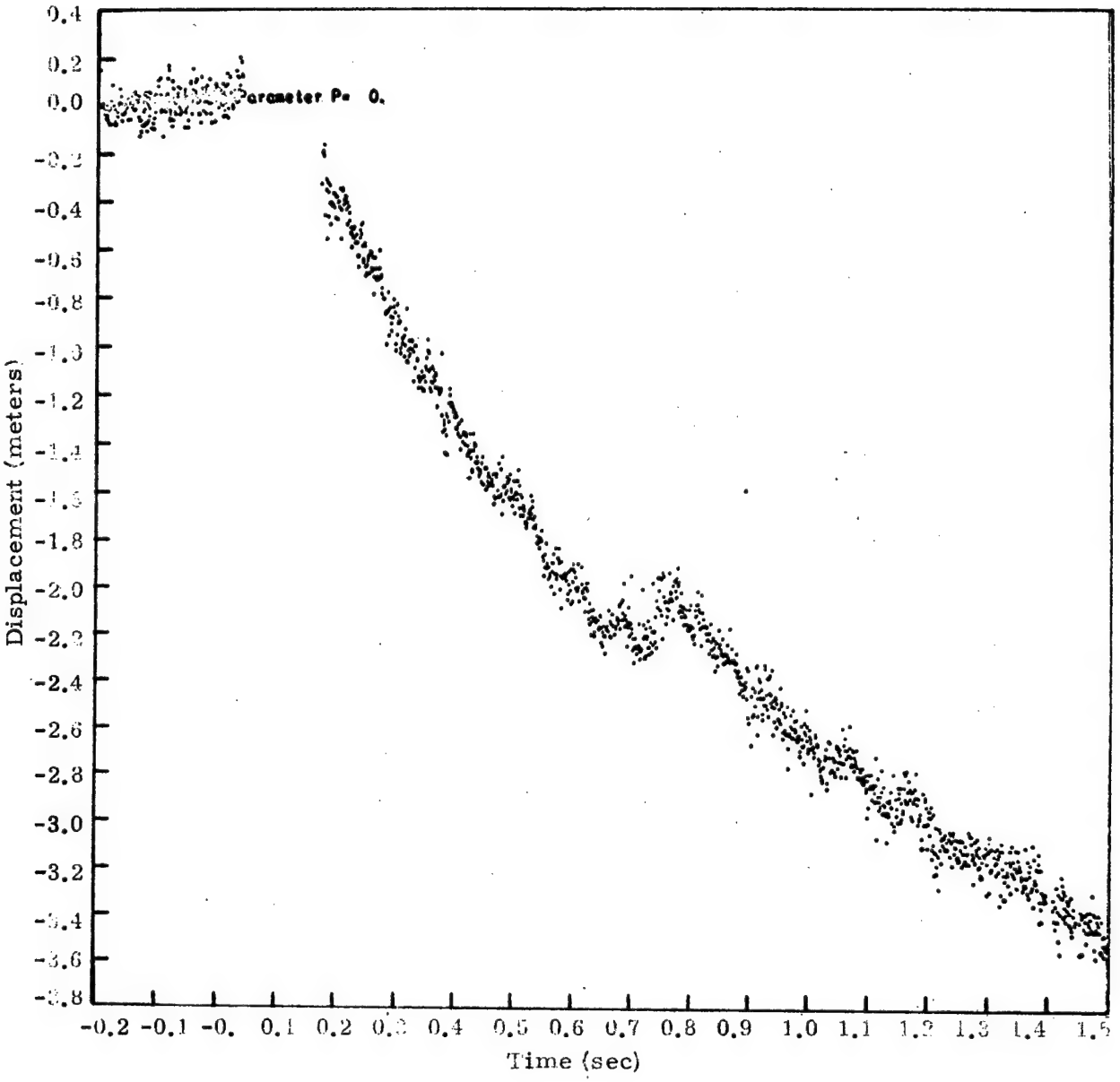

Fig. 25. Horizontal displacement, Target 9.

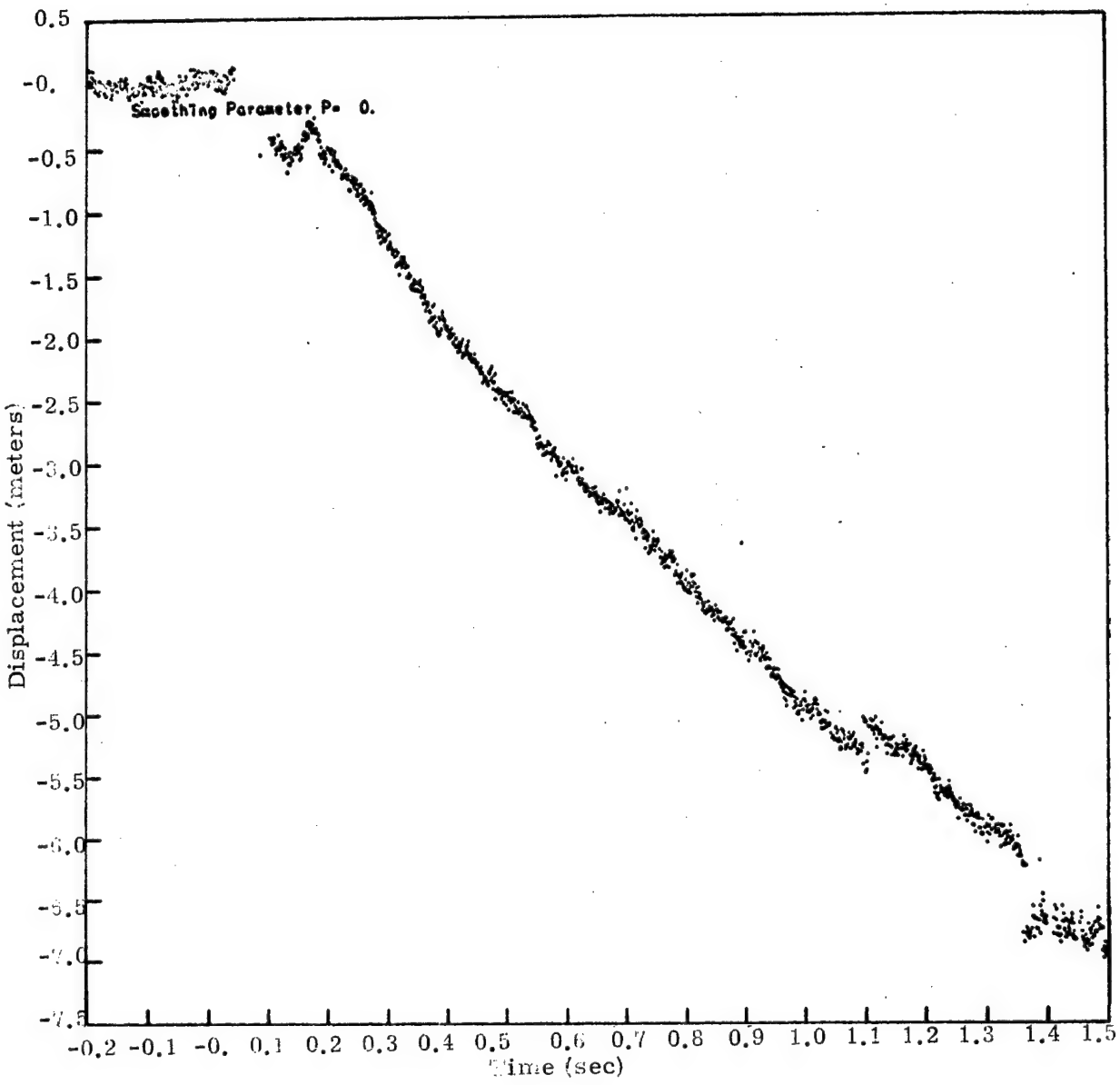

Fig. 26. Horizontal displacement, Target 10.

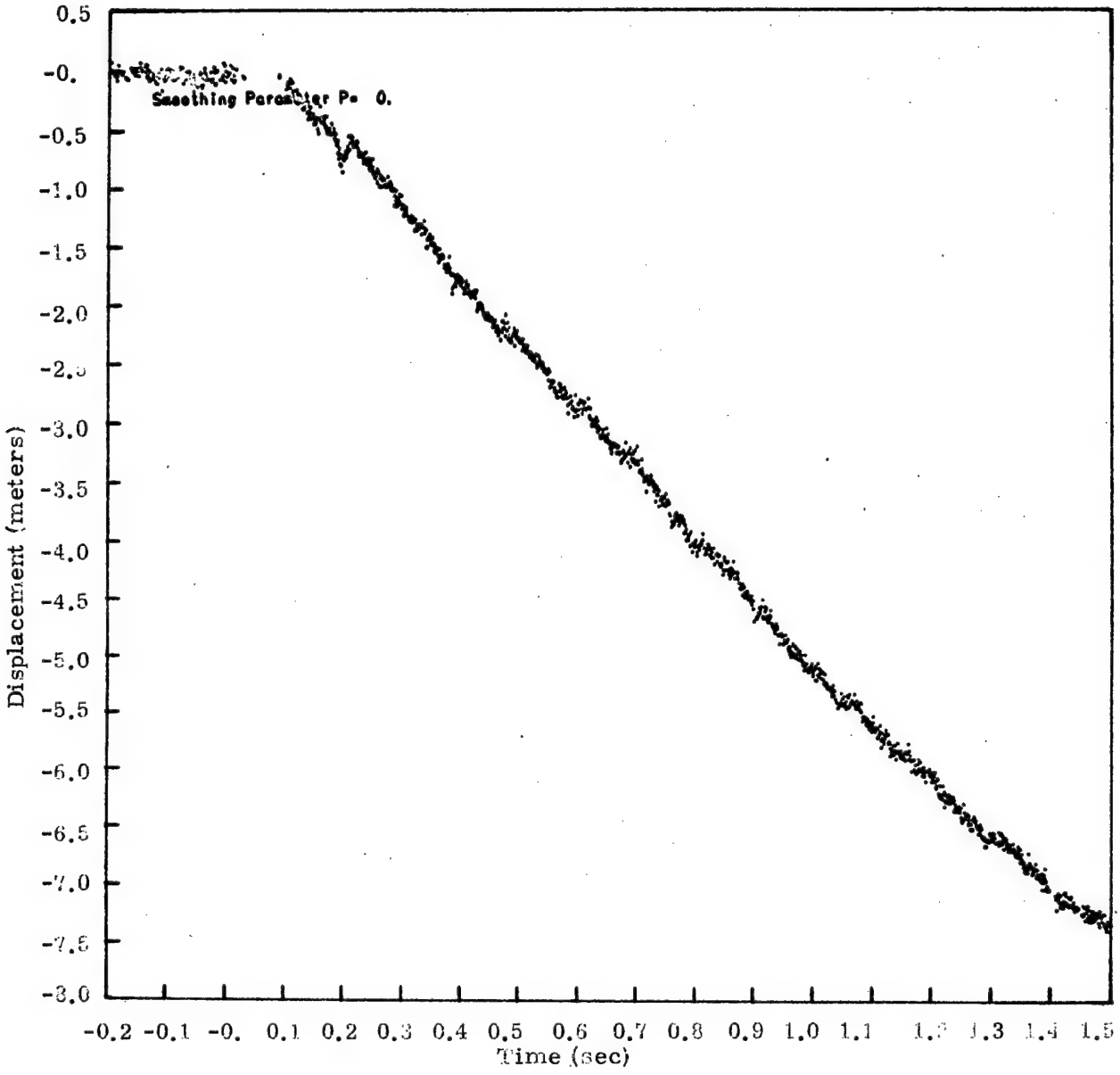

Fig. 27. Horizontal displacement, Target 11.

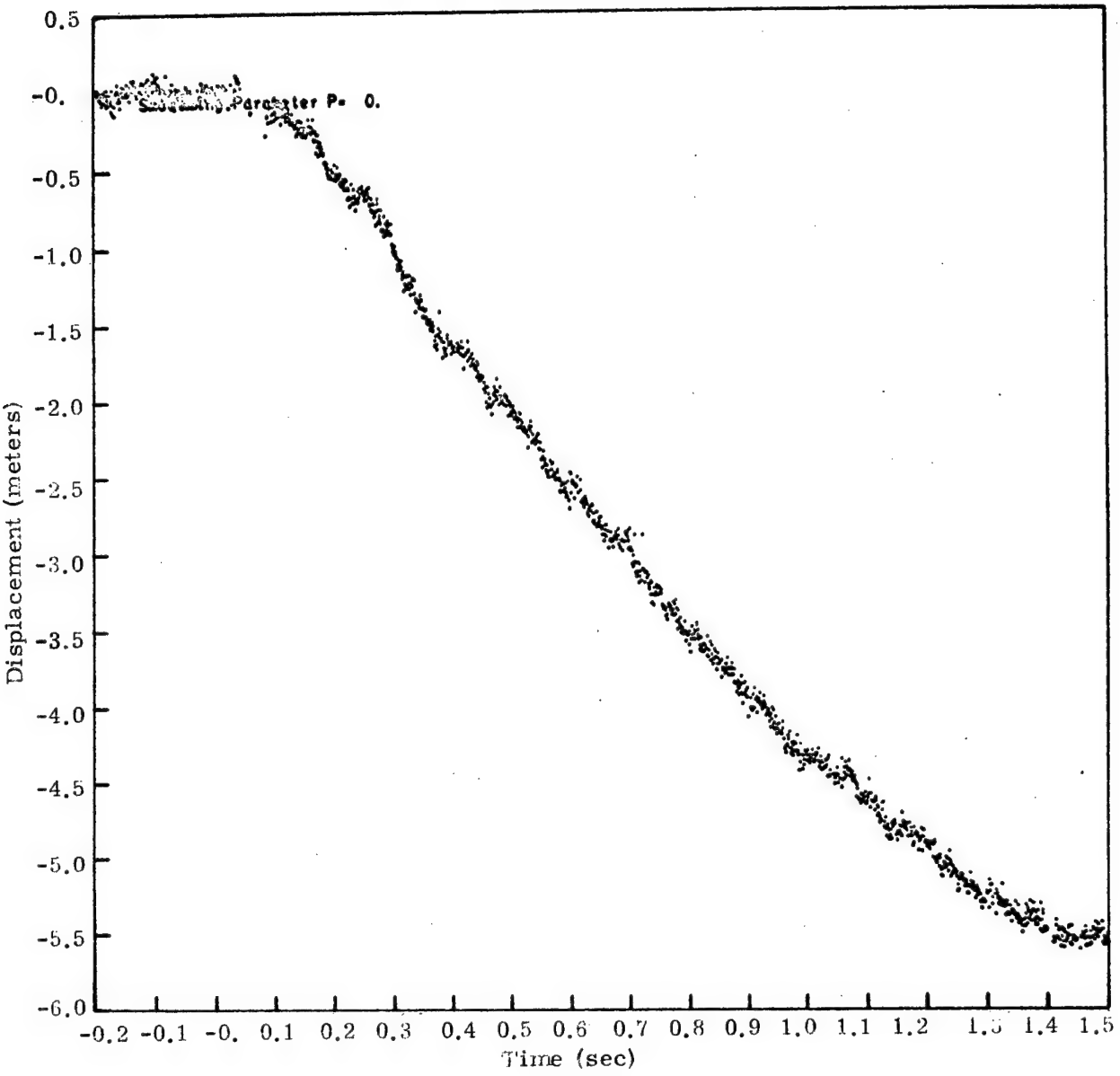

Fig. 28. Horizontal displacement, Target 12.

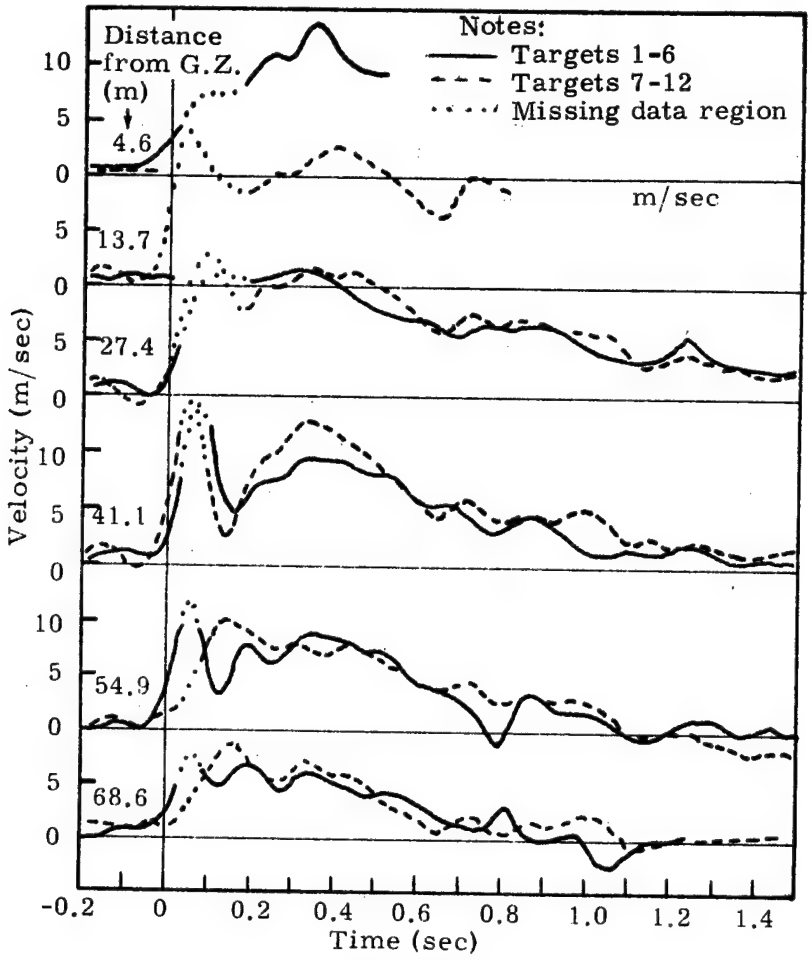

Fig. 29. Vertical velocity of targets.

(d) Effect of ground shock and Rayleigh wave on fiducial targets.

(e) Errors due to the ground shock induced air blast around ground zero which cause refraction of the light from the flares making the absolute position of the flares difficult to determine.

In order to evaluate the extent of theses errors and their possible removal, a frequency analysis and a filter technique are being developed. The results of this analysis will be included with later reports on the interpretation of the Palanquin surface motion results.

Figures 31 through 40 contain the vertical velocity of each target for two different degrees of smoothing, to provide the reader with the velocity record in greater detail, and to show the effect of the noise errors that are contained in the data.

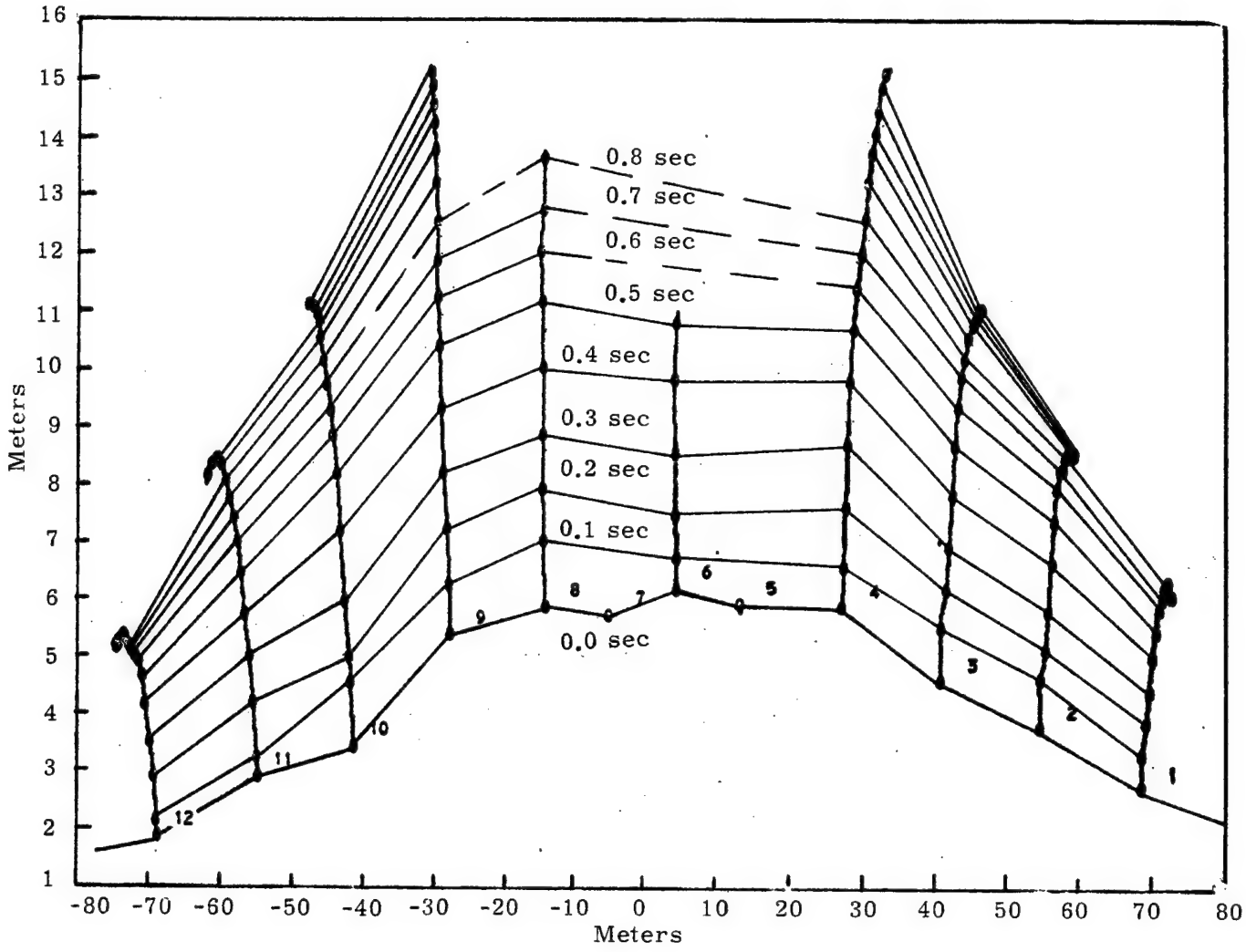

Fig. 30. Hodograph of flares.

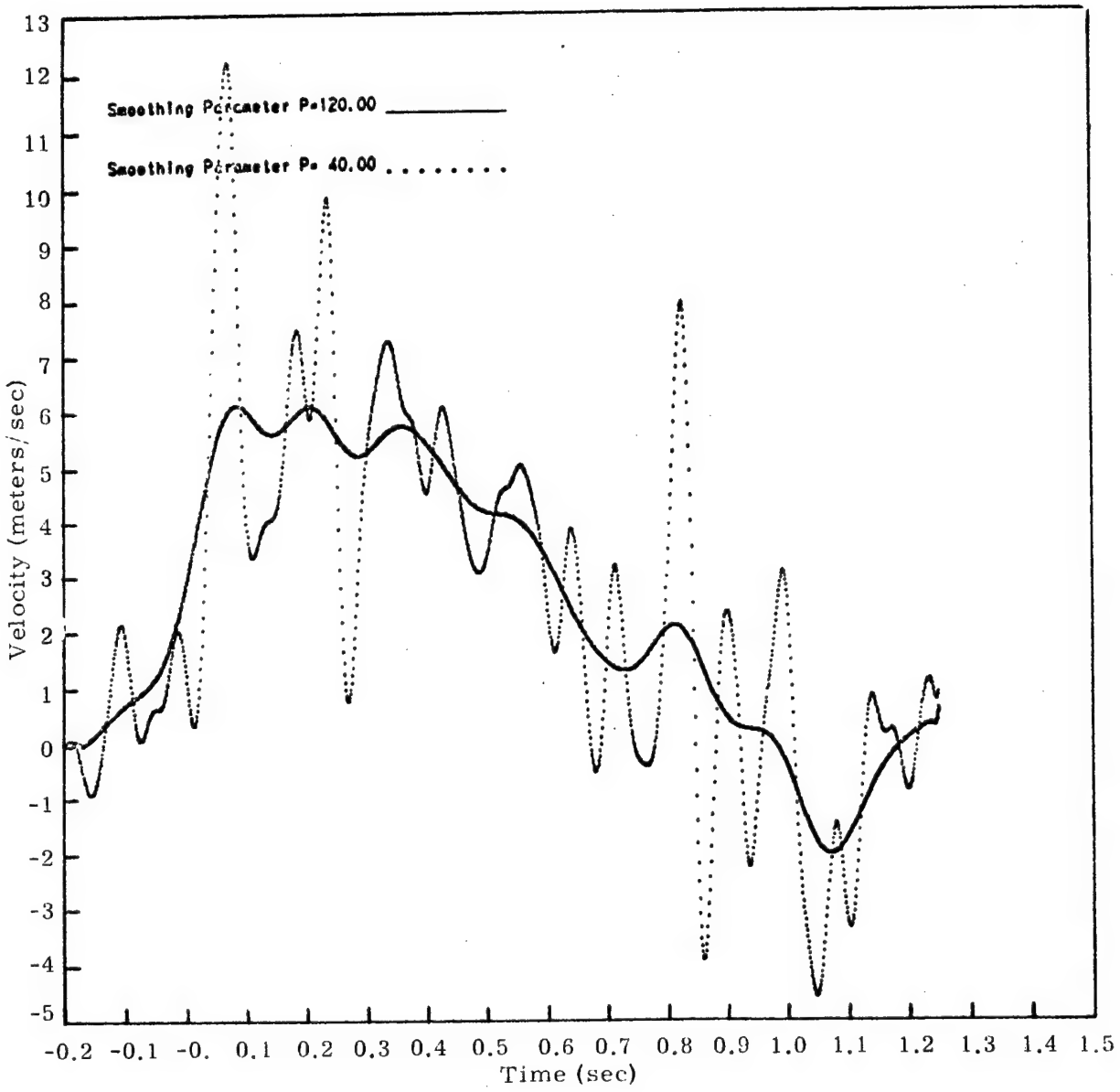

Fig. 31. Vertical velocity, Target 1.

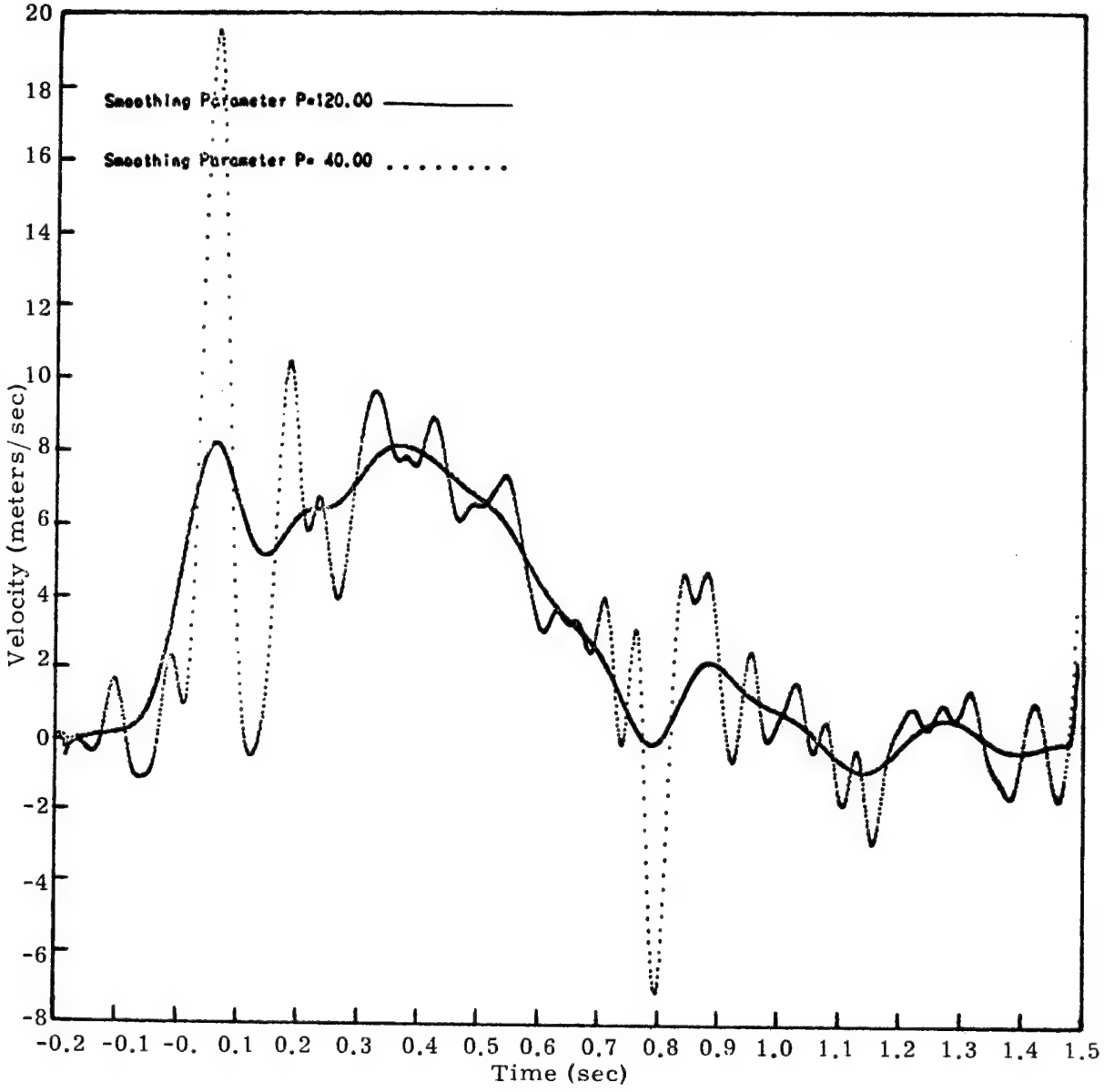

Fig. 32. Vertical velocity, Target 2.

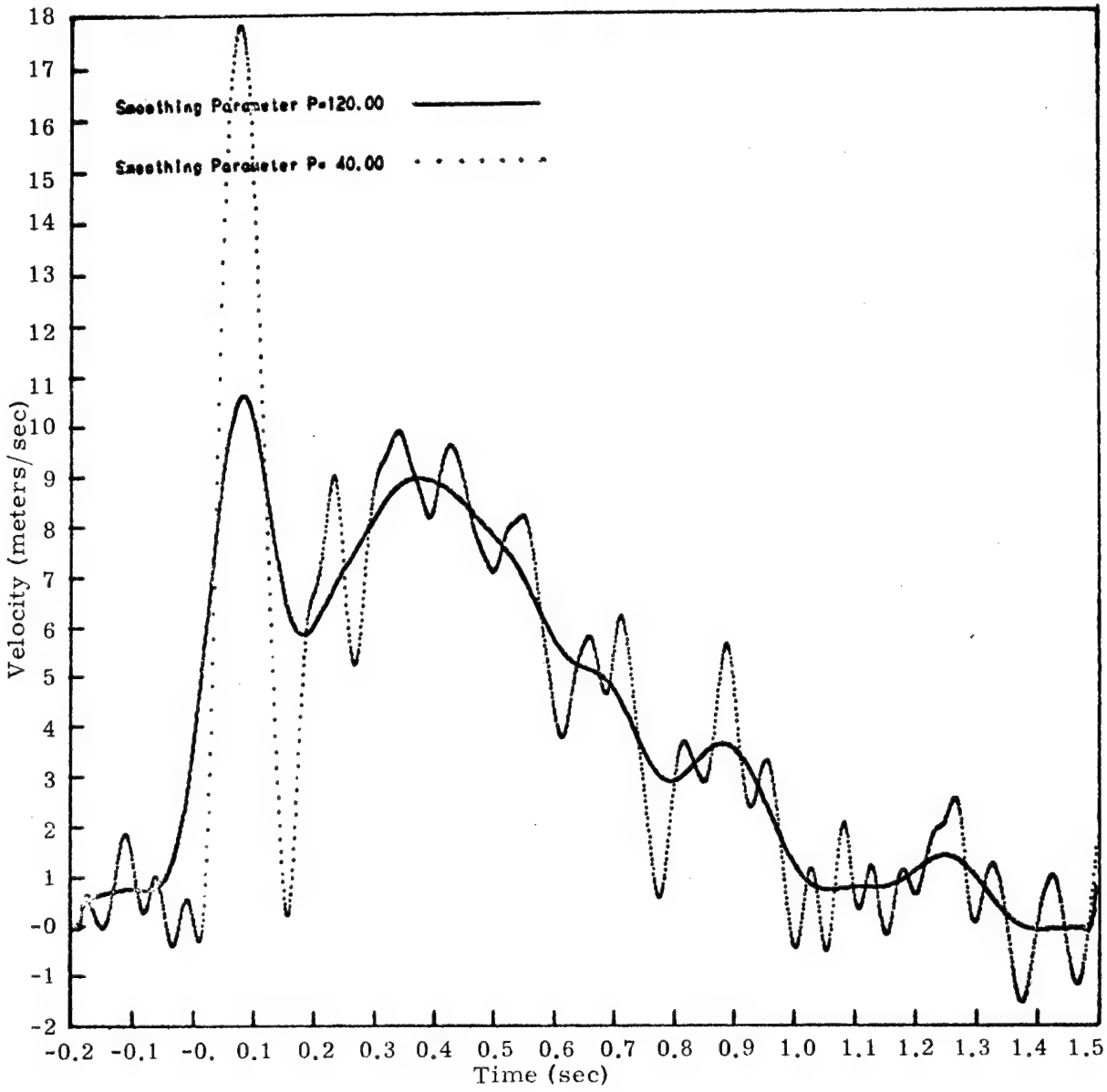

Fig. 33. Vertical velocity, Target 3.

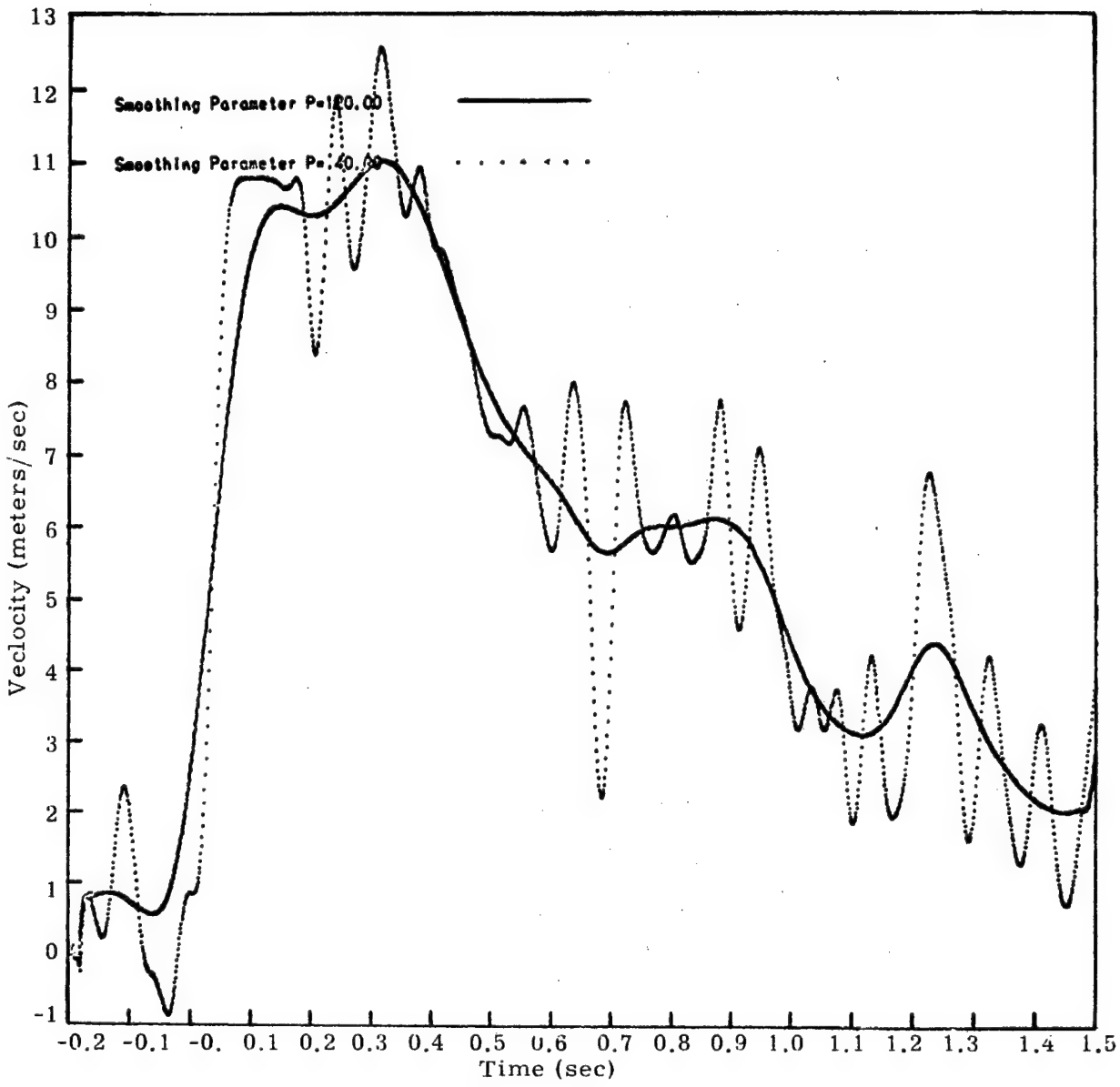

Fig. 34. Vertical velocity, Target 4.

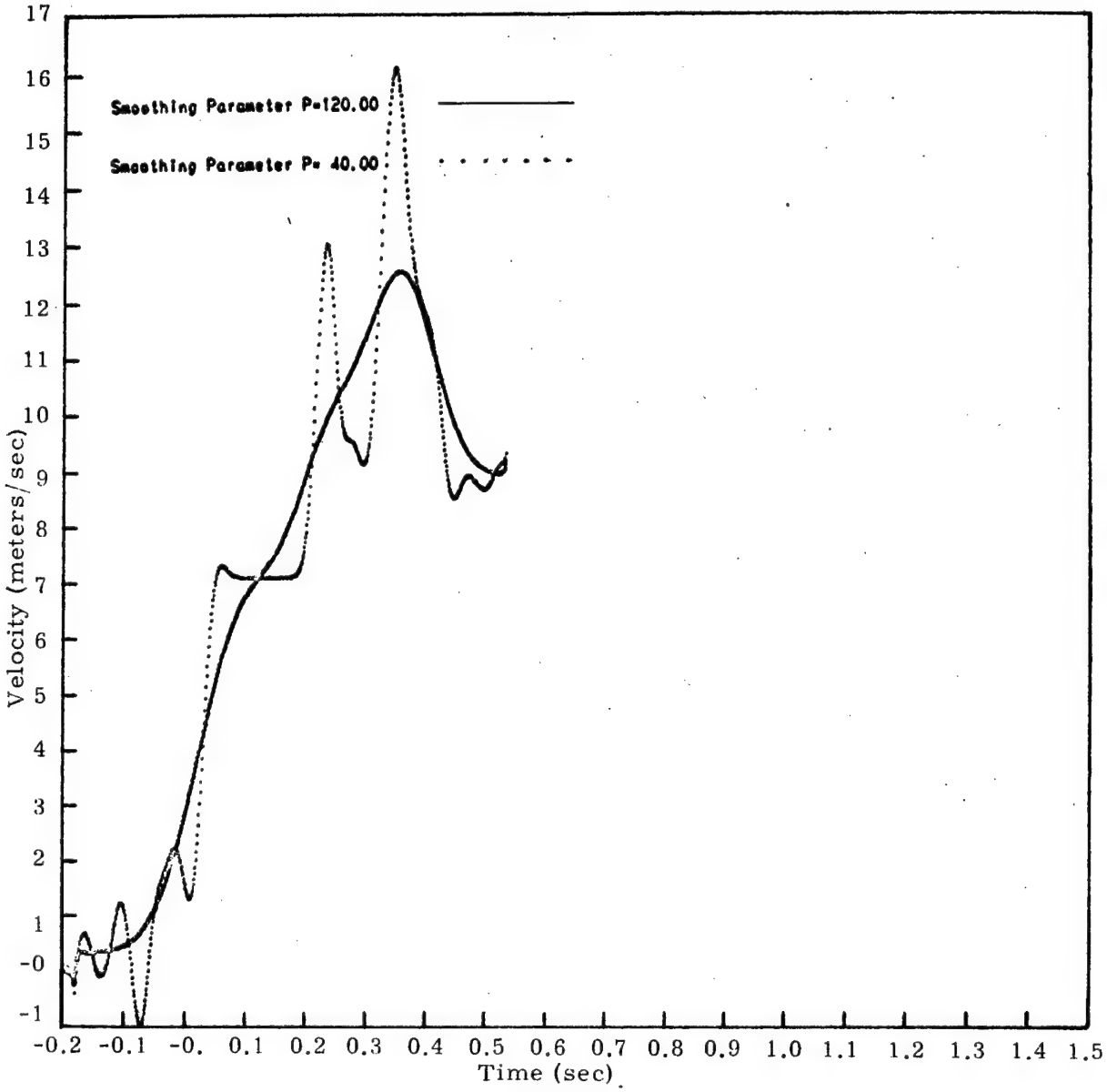

Fig. 35. Vertical velocity, Target 6.

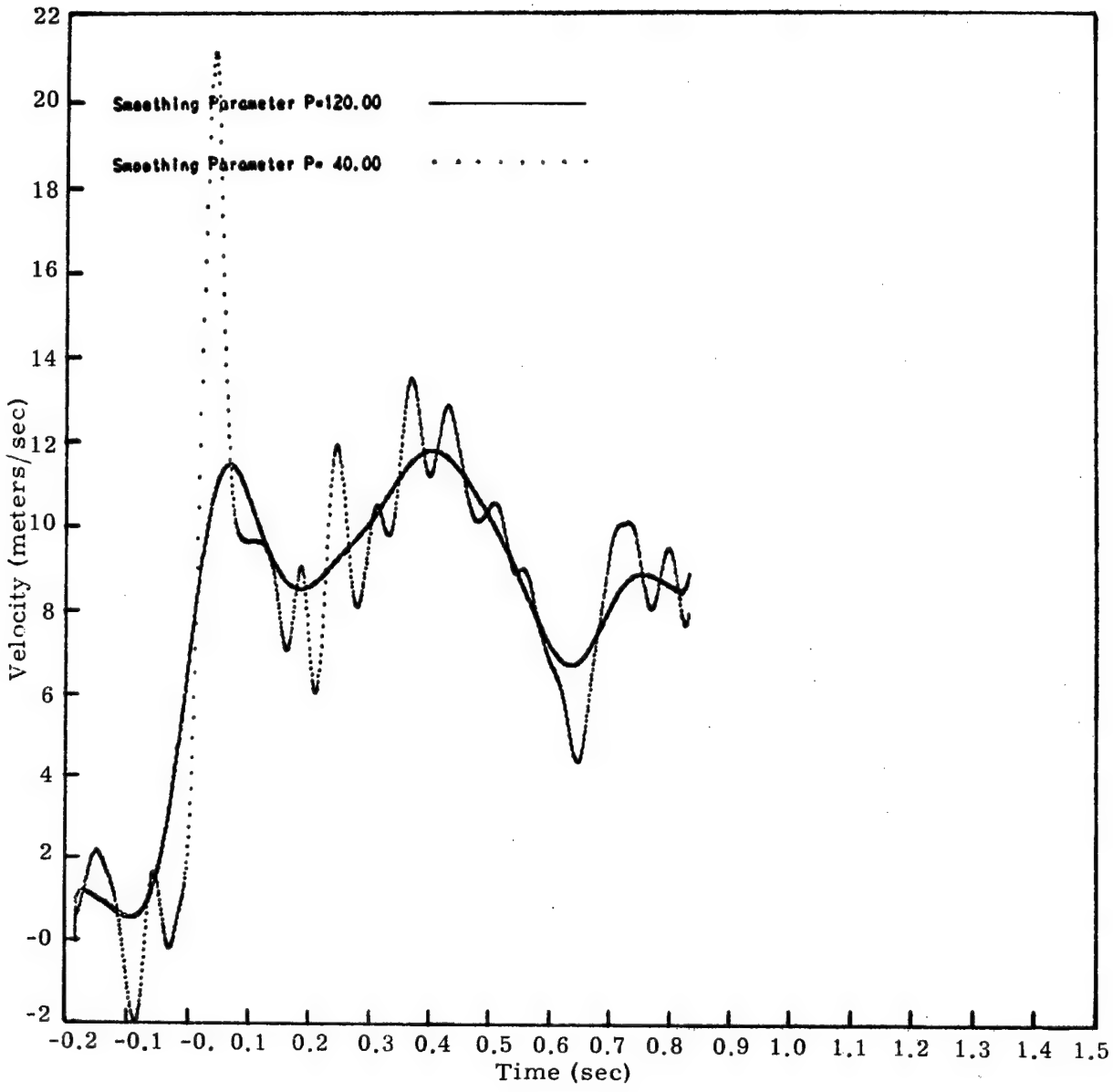

Fig. 36. Vertical velocity, Target 8.

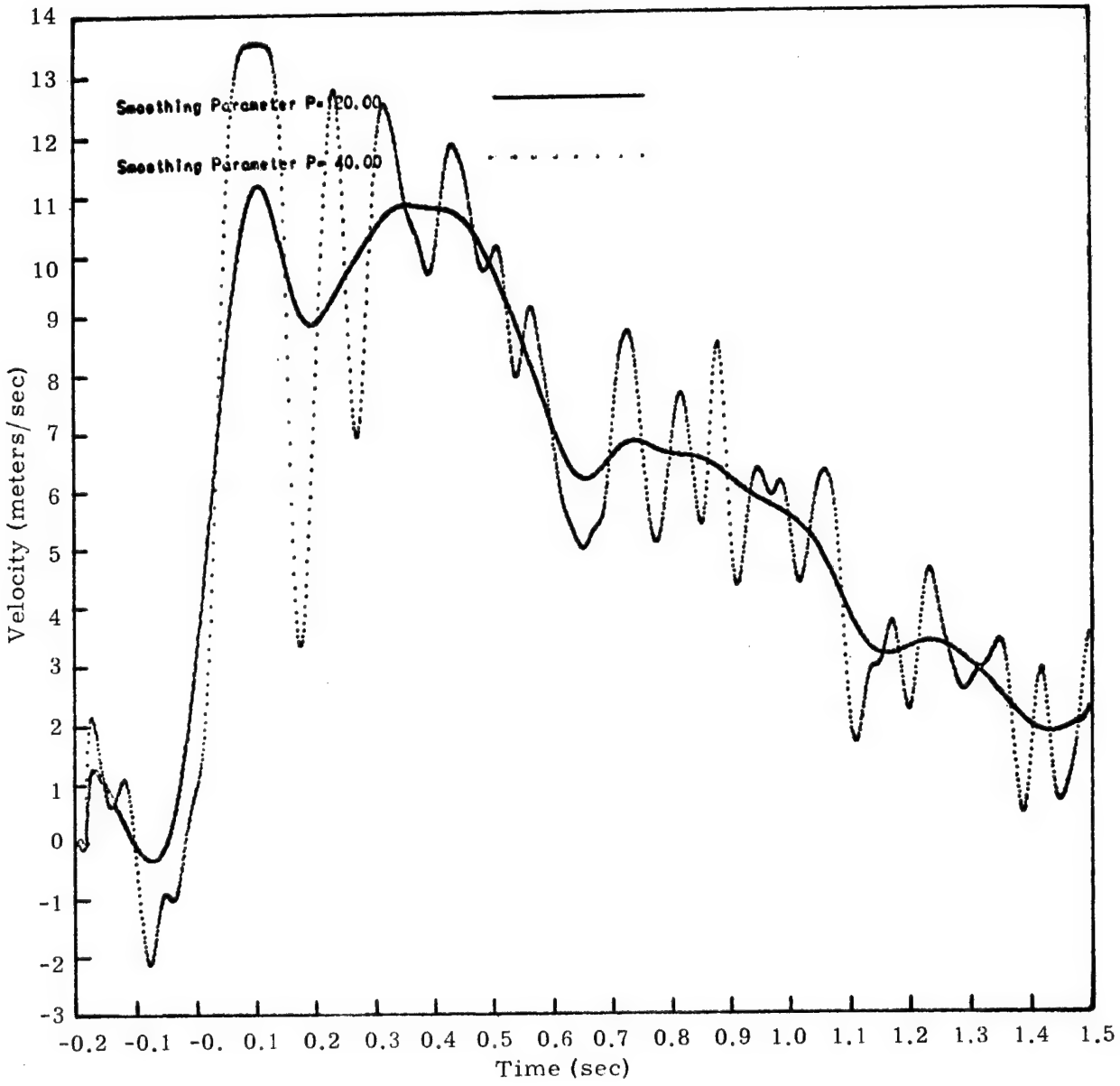

Fig. 37. Vertical velocity, Target 9.

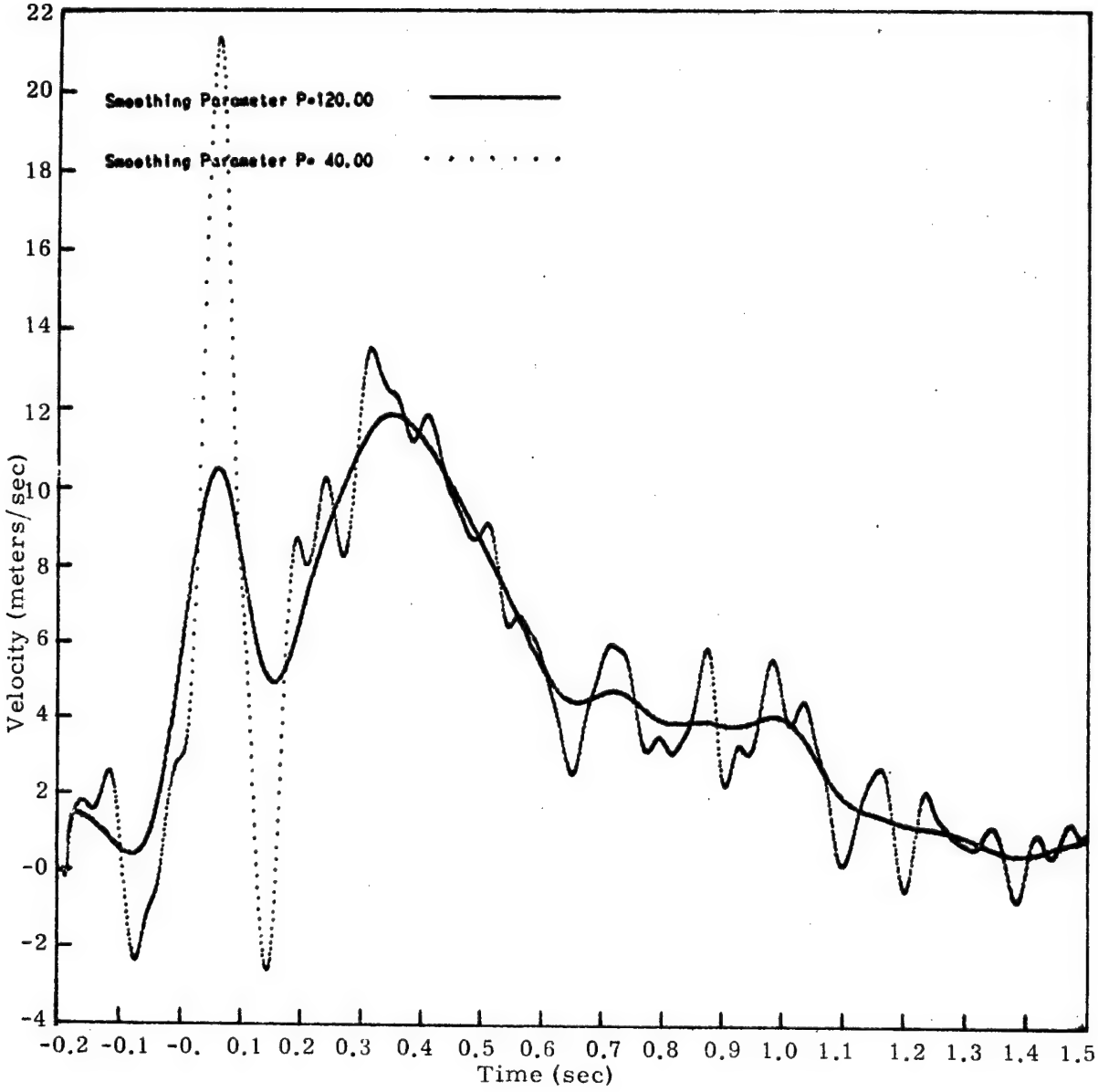

Fig. 38. Vertical velocity, Target 10.

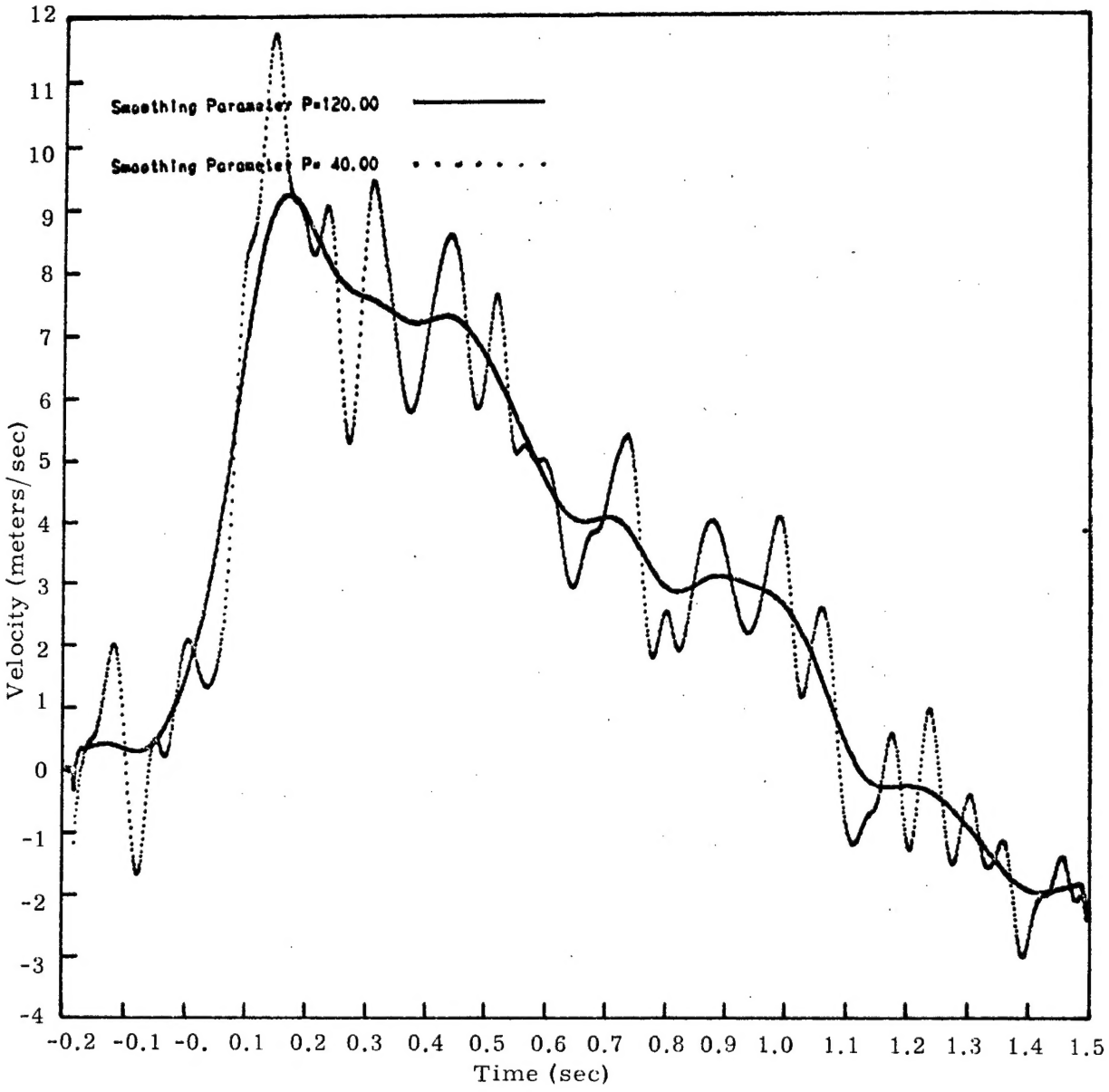

Fig. 39. Vertical velocity, Target 11.

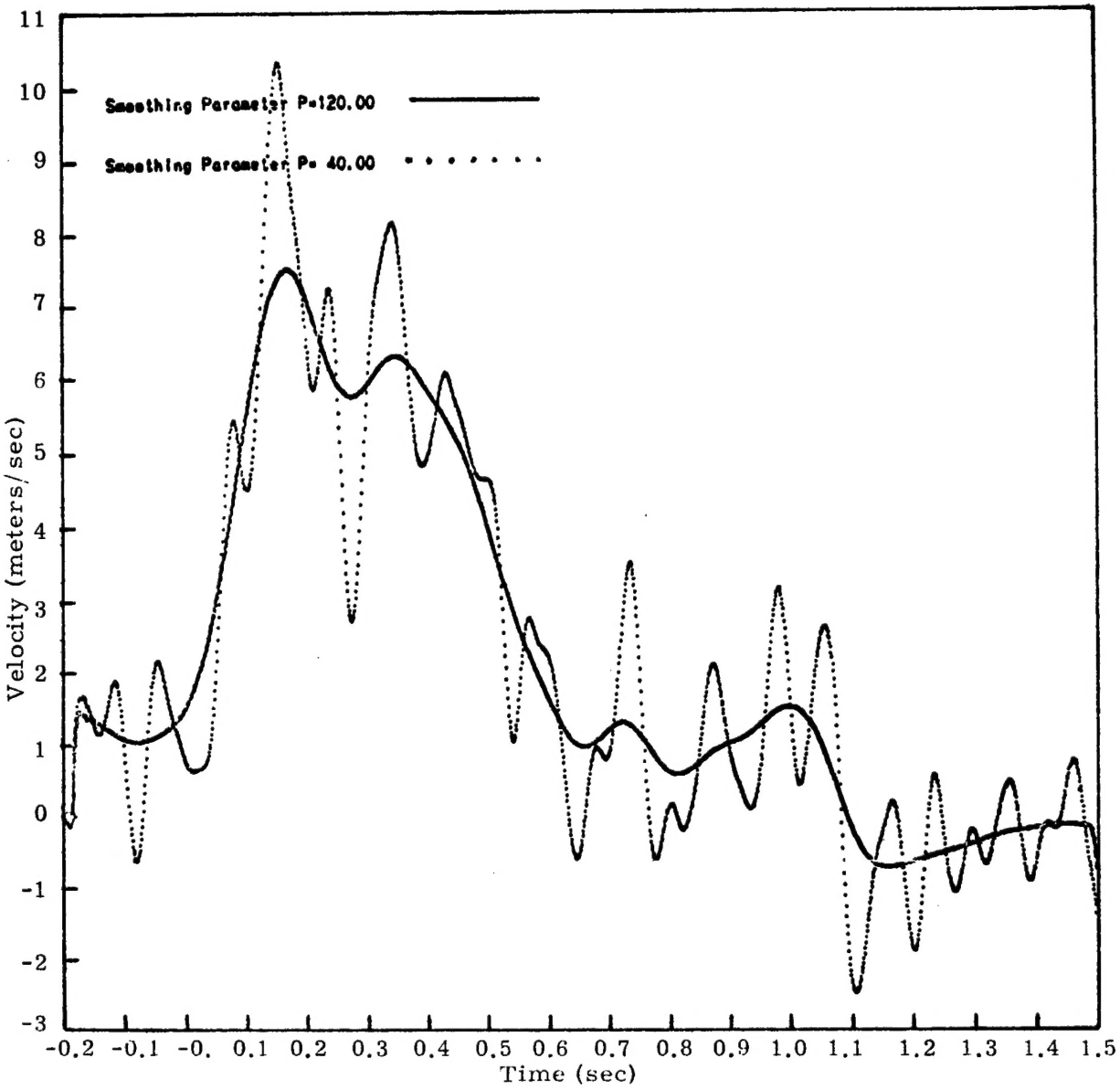

Fig. 40. Vertical velocity, Target 12.

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